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VOL. XIV, NO. 4 OCTOBER, 1932 Old Series Vol. XXX, NO. 4

The Journal of
Bone and Joint Surgery

THE ANGLE OF GAIT: A STUDY BASED UPON EXAMINATION OF THE FEET OF CENTRAL AFRICAN NATIVES

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"What is the correct position for the feet?" Physicians, physical directors, gymnasium instructors, and others interested in bodily welfare are repeatedly being asked this question. In earlier days only military authorities and dancing masters gave any apparent thought to this matter; they prescribed a position with the heels together and the toes separated to an angle of ninety degrees. That position is still maintained in the regulations of many continental armies, but chiefly for ceremonial purposes, such as "standing at attention", or "passing in review".

Bradford in 1897 was among the first to report actual observations on the subject and to record disapproval of a wide angle for the feet which he recognized as a distinctly artificial posture. His exposition of the common range in positions of the feet, from one of in-toeing to wide out-toeing (often associated with weakness of the feet), apparently received wide attention among other orthopaedic surgeons.

Although Bradford's interpretation of the normal posture gave it a moderate range of out-toeing, the parallel position of the feet, even with some amount of adduction, was seized upon as specific evidence of foot strength. Prompted, no doubt, by the desire to counteract the obvious weaknesses of wide out-toeing in flat feet, the profession first endorsed the parallel position of the feet as a therapeutic measure; soon, however, it became commonly accepted as the ideal foot posture.

The completeness with which opinion had swung in this direction is clearly reflected in a statement by Hoffman, quoted from his report on an examination of the feet of natives brought to the Louisiana Purchase Exhibition for the Philippine and Central African exhibits. His statement reads, "I must say that I was somewhat disappointed at not finding the straight or leverage gait as common among primitive peoples as I had

FIG. 1
Preparation of an examination area.

supposed; though, on the whole, it is far more common than among shoe-wearers".

The conservative conclusions of Bradford and Hoffman, who had given the subject careful study, seem to be overreached by many of the present advocates of the straight-toed position, who so emphatically affirm the correctness of this posture, alleging it to be characteristic of the Indians. Foundation for their assertions, however, is notably absent. Except for two works undertaken at Stanford University, under the able direction of Prof. A. W. Meyer, there is little in the way of formal examinations with statistical reports upon which definite conclusions regarding the correct position of the feet can be determined. One of the examinations, dealing with 229 male college and high-school students, was reported by Dougan; and the other, of 150 female college students, was reported by Patek.

While acknowledging the unique value of these later contributions, it is obviously desirable to check the results against conditions which prevail among people living in primitive surroundings; for it is only under such circumstances that we can be sure of interpreting natural gait without danger of the conclusions being perverted through the use of conventional footwear or by well-intentioned advice on the manner of walking.

An opportunity to examine such a group was recently realized in the expedition* sent to Africa in 1929 under the auspices of Columbia University and the American Museum of Natural History (New York). The

*The members of the expedition were Prof. E. T. Engle, Prof. W. K. Gregory, Prof. J. H. MacGregor, and Mr. H. C. Raven (leader). All of them are Staff members of one or both of the Institutions named.

FIG. 2
Making foot records at another site.

importance of such an examination was considered sufficient to justify its inclusion as one of the special objects of the Expedition.

Appreciation of the labors expended by the members of the Expedition in procuring the desired footprints is sincerely acknowledged. The work was not performed among the conveniences and facilities of a well equipped gymnasium, but had to be carried out under real difficulties. There was no smooth floor upon which to lay the kinetographic board on which the footprints were made. Whenever a suitable group of natives was gathered, a favorable area had to be selected in the open and, with native help, graded to a level surface. Usually this was done, and the subsequent examination performed, under the trying conditions of equatorial winds and rain, or beneath a blazing sun whose scorching rays made relaxation in a shady spot far more appealing to the members of the party than the effort to collect material for problems in which they had more of a friendly, than personal, interest.

Nor were the natives any too cooperative in the labor of preparing the necessary space. The digging, grading, and stamping down of loose earth involved work toward which they showed more reluctance than curiosity, and even less enthusiasm. At least, such was their attitude until Prof. Gregory conceived the happy idea of attaching a bit of pagan ceremony to the undertaking. This change was accomplished by means of a couple of resonant tin containers and with the help of Prof. MacGregor and Prof. Engle. With a few rhythmic drumming strokes and

lusty "yah! yahs!" as an overture, a very responsive chord was touched, with the result that quickly the long narrow space became crowded with enthusiastic dancers who now stamped down the earth with rapturous abandon (Fig. 1).

When the desired area had been prepared, the kinetographic board (about eighteen feet long and eighteen inches wide) was laid upon it. This was covered in order by a wide strip of inked fabric, similar in texture to typewriting ribbon, a corresponding stretch of paper, and a narrow sheet of muslin. Each native was directed to walk from one end of the board to the other so that an average of from six to eight footprints of each individual was thus recorded (Fig. 2). Fine longitudinal corrugations on the upper surface of the board were registered in the footprints on each sheet of paper, so that the angle of the feet to the line of body movement could be easily measured.

Impressions were gathered of 147 natives belonging to three tribal groups of the Belgian Congo,—the Ounyabonga, Wafaleru, and Wambuti (pigmies). The distribution as to sex and age within these groups was as follows:

Tribe	Male	Female	Children	Total
Ounyabonga	58	1	5	64
Wafaleru	21	26	20	67
Wambuti	8	3	5	16
	87	30	30	147

The total number examined has proven sufficient to determine the dominant habits in foot posture, as well as to give the comparative frequency and range of departure from the position in which the feet are most commonly used. Its subdivisions, however, are admittedly too small to yield reliable information on sex and age differences.

As remarked by Dougan, in his report, the results of such an examination emphasize two other phenomena, besides the angle of gait, that invite particular interest. One of them is the notable *Asymmetry* in the angle of the right foot and of the left foot in many individuals; the other is the *Variability* in the angle of each foot as demonstrated in the succession of footprints obtained in each test.

ANGLE OF GAIT

The term "Angle of Gait" has been applied to the habitual position or angle assumed by each foot to the line of motion as a person walks. Of course, if the normal or correct position is one in which the feet are parallel to that line, as inferred by the so called "Indian-walk", then any angle must be viewed as a departure from the normal. Consequently the fundamental nature of the question, introduced by that supposition, as to what is the normal position, justifies us in turning immediately to the ultimate result of the examinations.

Measurements of the total number of footprints (over 1000) gave an average angle of approximately seven and five-tenths degrees. Figure 3 shows the distribution of all footprints (both rights and lefts) within adjacent arcs of five degrees. The largest number of feet (twenty-nine per cent.) showed an angle of between five and ten degrees; the next largest group (twenty-five per cent.) lay between zero and five degrees; the third largest number (eighteen per cent.) had an angle between ten and fifteen degrees. On one side of that fifteen-degree arc, thirteen per cent. of the total number of feet showed an angle of from fifteen to twenty-five degrees of out-toeing. On the opposite side, a slightly greater proportion (fifteen per cent.) showed in-toeing, as represented in the three five-degree arcs between zero and minus fifteen degrees.

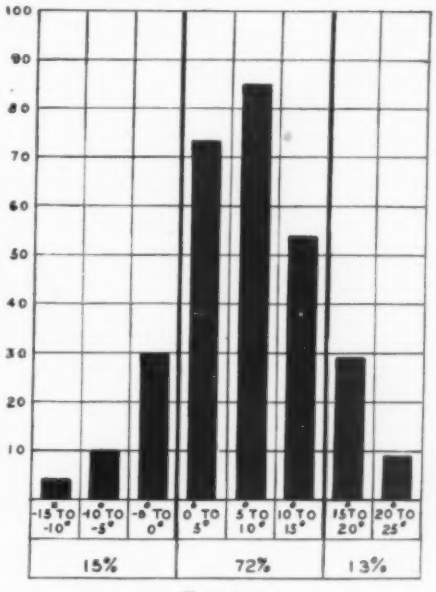

FIG. 3

Distribution of the angle of gait in all native feet (rights and lefts).

A second calculation was made on all feet included in the larger middle groups, comprising seventy-two per cent., to determine what their average angle might be. It gave a result of seven and six-tenths degrees, a mere shade wider than the seven and five-tenths degrees obtained as the average measurement of the total number of footprints.

VARIABILITY OF THE ANGLE

The positions which a foot assumes in a single series of steps are by no means constant in relation to the line of body movement. Thus, of the 147 natives examined, there were but three instances in which the angle varied less than four degrees in the three or four imprints taken of each foot. Variation in the angle of gait sometimes showed as great a difference as fifteen to twenty degrees in the impressions taken of a single foot. The average range of difference, however, was eight degrees, with the left foot showing a slightly greater amount, eight and three-tenths degrees, to seven and seven-tenths degrees for the right foot.

In previous studies by the author, it has been found that three or four tests on a single individual reduced this average range of variation from an arc of about eight degrees to one of five. Hence, if an allowance of two and five-tenths degrees be added on each side of an established average angle, the resulting arc will give a truer representation of how the examined foot is ordinarily used. For this reason, and in order to

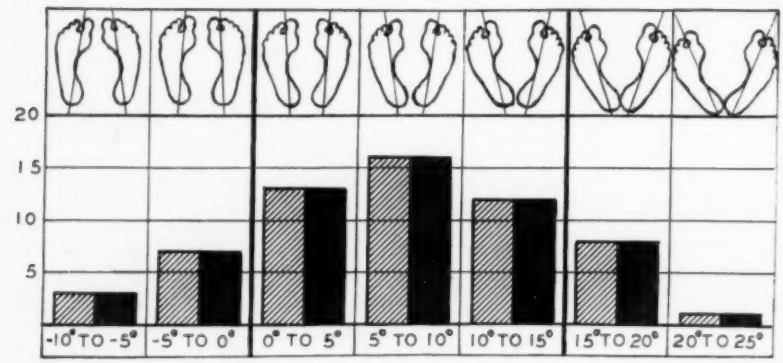

FIG. 4

Distribution of symmetrical cases showing the average angle in each group.

avoid cumbersome tables of statistics, it has seemed more satisfactory to group the feet within arcs of five degrees instead of using the actual measurements obtained from the examination.

SYMMETRY AND ASYMMETRY

Symmetry. Dougan stated that only six of the 229 students examined by him averaged the same angle of gait in their right and left feet. Patek found none in her 150 cases, and only five instances in which a difference of less than one degree was noted. Owing to the marked inconstancy in the angle of gait referred to in the previous paragraph under the term "variability", a coincidence of exact figures for each foot, averaged from a single test, seems too severe a criterion to employ in judging the presence or lack of symmetry in gait. If an arc of five degrees be recognized as an *allowable* range of normal variation, as suggested in the preceding paragraph, a truer and more practical estimate of symmetry is afforded. On such a basis, a grouping of the results of the African examinations within arcs of five degrees permits sixty of the 147 natives (forty-one per cent.) to be considered as having a symmetrical angle of gait. Their distribution, according to the width of the angle, is shown in Figure 4 and Table I.

TABLE I

DISTRIBUTION OF SYMMETRICAL ANGLE OF GAIT

Angle of Gait	*Total*	*Ounyabonga*			*Wambuti*			*Wafaleru*			*Totals Sex and Age*		
		M	F	C	M	F	C	M	F	C	M	F	C
−10° to − 5°	3	2							1		2	1	
− 5° to 0°	7	1			1		1	1	2	1	3	2	2
0° to + 5°	13	6		1		1	1	1	1	2	7	2	4
+ 5° to +10°	16	9	1	2	1	1		2		1	12	1	3
+10° to +15°	12	5						4	1	2	9	1	2
+15° to +20°	8	1						3	2	2	4	2	2
+20° to +25°	1									1			1
Total	60	24	1	3	2	2	2	11	7	9	37	9	14

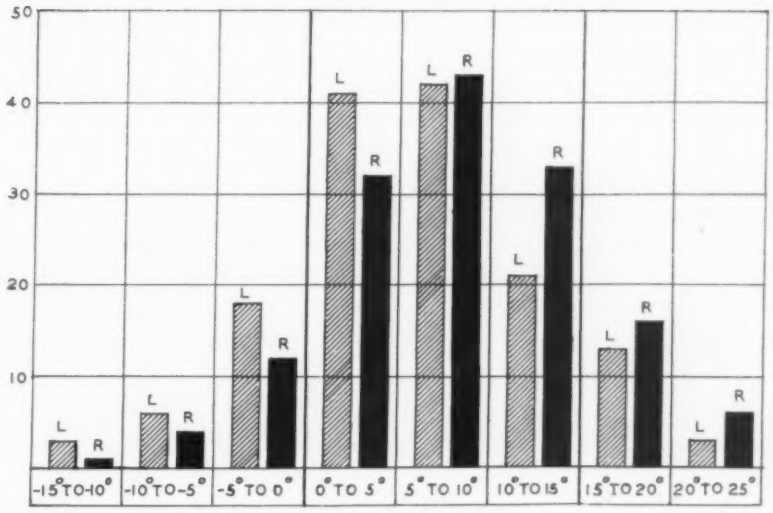

FIG. 5

Comparison of angles in left and right feet, showing dominance of smaller angles in the left and of greater angles in the right.

Asymmetry. When the angles of all right and all left feet are computed separately (Fig. 5), the results give a distinctly greater average angle, eight and three-tenths degrees, to the right foot, as compared to six and seven-tenths degrees for the left foot. The distribution is shown in the accompanying table (Table II). Although these figures are one degree higher than the averages obtained by Dougan (seven and two-tenths and five and eight-tenths degrees), the difference between the two sides is practically the same, and the right side has shown the greater angle in

TABLE II

TOTAL AVERAGES IN ANGLE OF GAIT IN RIGHT AND LEFT FEET

Sex and Age	*Ounyabonga (64)*			*Wambuti (16)*			*Wafaleru (67)*			*Total (147)*		
	No.	Average Angle		No.	Average Angle		No.	Average Angle		No.	Average Angle	
		R	L		R	L		R	L		R	L
Men	58	8.0°	8.0°	8	8.5°	6.0°	21	9.0°	8.6°	87	8.3°	7.9°
Women	1	10.0°	10.0°	3	7.3°	5.0°	26	7.9°	4.6°	30	7.9°	4.8°
Children	5	8.0°	6.2°	5	3.4°	−4.0°	20	10.2°	7.1°	30	8.9°	5.1°
Total	64	8.0°	7.8°	16	7.1°	2.6°	67	8.9°	6.7°	147	8.3°	6.7°

both examinations. Patek, however, obtained somewhat different results in her examination of female college students; her figures gave very similar averages of deflection of the feet, but with a half degree greater angle on the left side.

But the phenomenon of asymmetry does not receive its proper valuation in averages obtained from the total number of measurements. Inclusion of the sixty symmetrical records obscures the amount of postural difference characteristic of the really asymmetrical cases. If the latter be considered alone, the amount of asymmetry in right and left feet becomes manifest in appreciable proportions. Hence, for the eighty-seven natives with unequal angles of gait, the average amount of asymmetry measured approximately eight degrees for each side. Sixty-three had the greater divergence on the right side, while only twenty-four had it on the left. The greatest amount of asymmetry in a single individual, as based on his average figures, was nineteen degrees.

IN-TOEING AND OUT-TOEING

In-toeing. Bilateral in-toeing occurred in ten individuals,—five men, three women, and two children; in three of the adults, two men and one woman, the angle was minus ten degrees.

In-toeing on one side only was present in twenty-four instances. In accordance with the foregoing observations on asymmetry, in which the smaller angle falls more frequently on the left side, in-toeing was present in eighteen left feet and in only six right feet. The extreme examples for the right and left sides were minus twelve and minus fifteen degrees respectively.

Dougan recorded one case of bilateral in-toeing, while unilateral in-toeing was present in four cases for the right foot, and twelve cases for the left. His extremes were minus six degrees for the right foot and minus eight degrees for the left.

Patek, with no instances of bilateral in-toeing, listed six unilateral cases on the right side and two on the left. A negative angle of five degrees was the maximum for each side in her results.

Out-toeing. As previously stated, seventy-two per cent. of all the native feet examined were included in the arc between zero and fifteen degrees. This arc, through such strength in numbers, might be regarded as representing an acceptably normal range for the average angle of gait, with fifteen degrees as the outside limit. Outside of that range, nine African natives showed bilateral out-toeing,—four men, two women, and three children. In every case except one, the average angle of the two feet fell within an arc between fifteen and twenty degrees. The single exception was a child whose feet showed a twenty-five degree angle on each side, and, according to notations which accompanied the footprints, this child was one of the few individuals seen during the Expedition, who had a definite static derangement of the feet.

There were twenty cases of unilateral out-toeing; thirteen examples occurred in the right foot and seven in the left. Twelve of these twenty individuals were adult males. The greatest average amount of out-toeing in these asymmetrical cases was twenty-five degrees for the right side, and for the left side, twenty-four degrees.

In Dougan's examination, nine right and four left feet showed an average angle in excess of fifteen degrees. His maximum measurements were twenty-one degrees on the right side, and sixteen and five-tenths degrees on the left. In Patek's statistics only three right and three left feet showed an average angle exceeding fifteen degrees, with the greatest average angle of deflection amounting to eighteen degrees on each side.

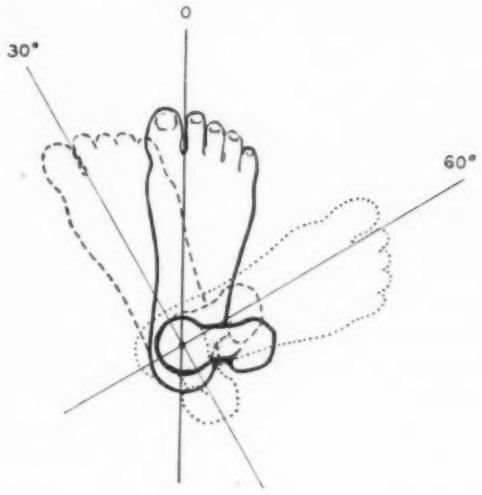

FIG. 6

Correlation of lateral movements of the feet with the 90-degree arc of hip rotation.

DISCUSSION

The position of the foot to the line of body movement, as implied in the term "Angle of Gait", is not a fixed phenomenon like the single plane of movement between adjacent segments of a hinge joint,—as, for example, flexion and extension of the foot on the leg, or of the leg on the thigh. Although a certain amount of lateral movement of the foot is permitted by the subastragalar articulation and by the knee, the design of these joints is such that, under the assumption of body weight, all segments of the lower extremity (foot, lower leg, and thigh) gravitate into a fairly constant relationship with each other; and the angle of the foot in walking or running is determined essentially by the position of the femur in its ninety-degree arc of rotation at the distant hip joint (Fig. 6). Consequently, the angle of gait is not so much an entity in itself as an index to the functional position of the femur within its quadrant of rotation.

The longitudinal axis of the foot projected upon this quadrant coincides with the juncture of its inner and middle thirds. In-toeing is, therefore, synonymous with internal rotation of the femur, having a maximum range of about thirty degrees; and out-toeing, with external rotation and its possible range of sixty degrees. Consequently, when a joint so freely movable as the hip serves as the axis for the lateral positions of the foot, variability in the angle of gait is hardly a matter for surprise. In fact, the ninety-degree range of smooth and unobstructed lateral motion allowed in the hip speaks for the remarkable coordination in the action of the hip rotators, whereby the angle of gait is maintained as constantly as it is within a very limited segment of that quadrant.

The functional position of the femur, as indicated by the angle of gait, takes into account with every step the combined requirements of locomotion and of the preservation of body balance. The hip joint is

extremely sensitive to changes in the lateral balance of the body. That sensitiveness is manifested in the different positions a foot occupies in each series of successive strides, and underlies the phenomenon referred to as "variability" in the angle of gait. Locomotion in its detailed workings is a subconscious act. We may voluntarily control the direction and the speed of our movements; but the performance of the act in all its intricate details, involving the strength and the sequence of individual muscle actions for movement and for protecting the vertical balance of our bodies, is under control of a wonderfully developed inner mechanism which operates quite independently of our conscious thought.

Continuous variation in the position of the feet may seem a very unnecessary and even an undesirable feature as we seek to identify some ideal walking angle; but, when we realize that it represents specific responses of the rotating muscles of the hips which are constantly adapting the position of the feet in protection of the balance of our bodies, the phenomenon demands far greater respect. We are then able to appreciate the fact that *variation* in the angle of gait is as normal as the angle of gait itself.

There are three distinct phases of foot function,—standing, walking, and running; each of them imposes somewhat different functional requirements. When a person stands, the feet must be placed so as to preserve body equilibrium in all directions. Their length takes care of forward and backward balance, while lateral balance may be secured by either an outtoeing position or by separation of the feet.

Running and walking, as phases of locomotion, are quite different phenomena from that of standing; they are dependent upon an actual loss of body balance in a forward direction. In running, the weight center of the body is allowed to fall well forward into a position where the leg and foot can give it a strong forward push from behind; subsequently, each leg in turn catches the body weight and gives it another push as the body advances. In running and sprinting, athletes point their toes straight forward; their feet are brought close to the mid-line in order to exert their propelling effort as directly behind the center of weight as possible, and their parallel position affords the maximum leverage action. During such movement, the element of lateral balance is reduced to a minimum because of forward momentum of the body mass, and because the weight center is so far off balance in that direction; hence, if a runner is tripped, he falls forward and face-downward. Similar lack of need for lateral support is observable in the vertical position of a rapidly rolled hoop.

With running and standing as opposite functional extremes in the phenomenon of lateral balance, different speeds in walking represent the intermediate phases. Just as the hoop tends to fall on its side as its speed lessens, so our need for lateral support increases with a slowing of gait, and decreases with faster movement. Such direct relationship between the rate of body movement and lateral stability is naturally manifested in corresponding changes in the position of the feet whereby necessary stability is furnished.

As previously stated, lateral support may be procured either by turning the toes outward or by separating the feet. Which of these two methods fits most effectively into the mechanics of walking?

In Figure 7, AA and $A'A'$ represent the lines of movement followed by the center of body weight. The two types of stride are illustrated: the first, with seven and five-tenths degrees of out-toeing; the second, with the feet separated and parallel. Both strides are given equal lateral stability by the heads of the fifth metatarsal bones E and E' being p aced the same distance from the mid-line. The difference in the two strides lies, therefore, in the distance of the points F and F', representing the center of the ankle, from the mid-line; from these points the propelling thrust is exerted against the weight center as the body moves forward. It may be noted that in the first case, with the heel close to the mid-line, the thrust from F against the weight center W throws the latter forward but *within the outer margin of lateral support* (of the opposite foot) almost immediately after it passes the toes. At a similar point, W' in the parallel stride, the thrust from F' is directed definitely *outside the margin of lateral support* furnished by the foot in front.

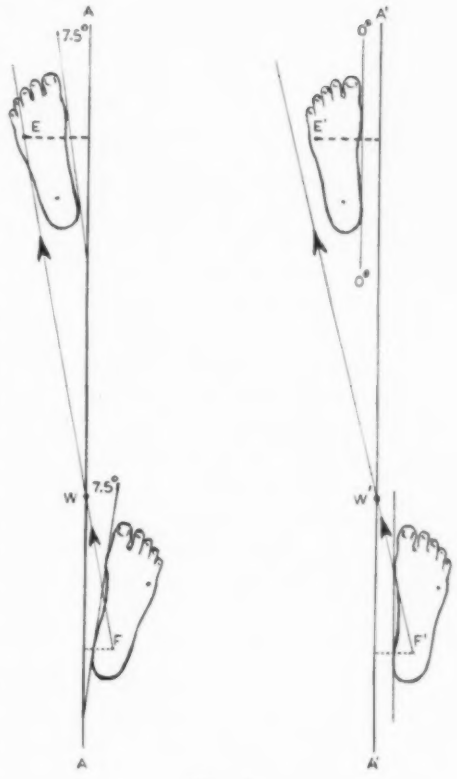

FIG. 7

Comparison of the mechanics of a stride in 7.5 degrees of out-toeing and with the feet parallel. (See text.)

The foregoing analysis recognizes two functional elements in the mechanics of a stride: (1) lateral stability, effected by widening the position of the feet as a base, and (2) a forward thrust from behind the moving center of body weight. In regard to the latter, the closer the heels are used to the mid-line, the more directly forward is the thrust exerted against body weight, so that a correspondingly lesser amount of disturbance is imposed upon lateral balance. Whereas, with a separation of the heels, increased obliquity is given to the forward thrust, which tends to rock the body from side to side with each step. A moderate amount of out-toeing meets most effectively the requirements of lateral balance in walking, while its approximation of the heels insures a smooth and direct forward movement. In contrast, a parallel position, with the feet close to

the mid-line, sacrifices a degree of security in lateral support, or, if the feet are separated, obliquity of the forward thrust tends to disorder the lateral balance and to introduce a swaying of the body in its forward movement.

This interpretation designates a moderate degree of out-toeing as the ideal position of the feet in walking; at the same time it recognizes that the angle is constantly subject to change according to the rate of movement. Moreover, it seems to explain the uniform predominance of such an angle in all three of the examinations that have been undertaken. If the African tests may be accepted as revealing most truly the natural gait, then seven and five-tenths degrees can be regarded as the angle of choice; and, with two and five-tenths degrees of allowable variation, the arc between five and ten degrees would represent the ideal range. This estimate would give an angle of between ten and twenty degrees between the two feet in ordinary active walking. A more rapid pace would tend to close that angle, and a more leisurely stride, to widen it.

As for the position of the feet in standing, an angle of forty-five degrees between the feet, as suggested by Bradford, seems the most reasonable and natural. For at this angle the spread of the feet across the balls for lateral stability is greater than the length of the feet for anteroposterior balance.

Factors have been identified which tend to influence a widening in the usual angle of gait,—such as age, stoutness, exhaustion, uneven surfaces, anatomical variations, and pathological disorders, although there is no absolute relation between these factors and the angle of the feet. As examples, aged and heavy individuals are to be seen who walk "pigeon-toed" instead of toeing outwardly as the rule would presuppose; also flat-foot cases may toe out widely or they may toe in. The chief value of these observations, however, is to emphasize the fact that the angle of the foot is not a fixed affair, but that it has a possible range of variation corresponding to the arc of rotation of the hip joint, which is the real axis for the angles assumed by the foot.

The range of difference in the positions of the feet of African natives was distinctly greater than the range observed in both examinations of American students. This does not seem strange, however, when we consider the difference in their respective environments. Smooth floors and pavements of civilized communities minimize changes in the position of the feet and would tend to establish a more constant and habitual angle; in contrast, the uneven ground surfaces of a primitive environment and less formality in the native mode of life would encourage much greater freedom in the movements of the hip and feet that could very naturally have been registered in the angles of their footprints.

Asymmetry in the angle of gait was first observed by Bradford, and also discussed by Dougan and Patek. In their examinations, as well as in the present one, it has been sufficiently prevalent and of such degree as to designate it a common and definite actuality. Dougan suggested as its

cause greater dependence upon the right leg for bodily equilibrium, or better muscular development on that side through its greater use in other purposes. Patek was apparently not impressed with these explanations, as she found the average angle greater on the left side. In certain physical activities—such as ball-throwing, spear-casting, etc.—which are more common to males than to females, the right foot is used at a much greater angle by right-handed persons than the left; such activities, engaged in from early childhood, might have shown some bearing on the sex differences if right-handedness and left-handedness had been correlated with the foot examinations. But too much promise cannot be given to this possible explanation, for in the African examination greater deflection of the right foot was about equally spread among the men, women, and children.

Right-leggedness and left-leggedness may be connected with this asymmetry, but, under most favorable conditions, dependable data on this point are difficult to obtain and the attempt was out of the question in the native tests. It seems reasonable to believe that the condition may result from the combined effect of multiple minor asymmetries in structure of the two sides, or in some cases may be no more than persistent habit as a sequela of previous injury. At any rate, when more than half of the natives showed an average of eight degrees of asymmetry with the greater angle either in the right or in the left foot, its source must involve a multiplicity of factors which are now obscure.

CONCLUSIONS

Three formal examinations of the feet of presumably normal individuals (two, of American male and female college students; the third, of African natives) are in agreement in demonstrating that the predominating position of the feet in walking is one of moderate out-toeing.

The tests contradict the idea commonly held that a parallel position of the feet—the so called "Indian method"—is the correct and natural posture.

It is true that there was a somewhat greater proportion of natives who showed a straight, or in-toeing, position than obtained among college students; but, on the other hand, the proportion of out-toeing in excess of fifteen degrees was also greater among the African natives. Both of these postural groups represented merely small minorities on either side of the large middle group, comprising seventy-two per cent. of all the feet examined.

The average angle of gait among African natives was seven and five-tenths degrees. Although this figure is slightly greater than that obtained from American college men and women, the average differences resulting from each examination are too small to have any particular significance.

Inconstancy in the angle of gait, as shown in any series of successive steps, has been strikingly emphasized in all three of the examinations; so

much so that an arc between five and ten degrees of out-toeing seems to give a more faithful estimate of how a foot is normally used than an arbitrary angle of gait arrived at by mathematical averages. It was within that arc (between five and ten degrees) that the angle of gait in the greatest number of native feet was located.

Physiological analysis of walking concurs with the foot examination in designating seven and five-tenths degrees in out-toeing (an angle of fifteen degrees as formed by the two feet) as the ideal angle of gait in ordinary active walking. Rapid movement tends to narrow that angle, slower movement to widen it.

An angle of forty-five degrees between the two feet seems to be the most natural position in standing.

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THE TREATMENT OF FRACTURES IN THE LIGHT OF THEIR ISCHAEMIC COMPLICATIONS*

BY G. R. GIRDLESTONE, F.R.C.S., OXFORD, ENGLAND

May I begin by saying how deeply I feel the honor and the responsibility of addressing the American Orthopaedic Association. Part of the responsibility, however, rests upon your President, Dr. Gallie, who was kind enough to invite me to do so. This subject has been chosen because the relationship between the activities of a bone and the circulation in it is fundamental, and because we can hardly remind ourselves too often that a consideration of the possible defects of the circulation within a broken bone and in its environment should be allowed to exercise a profound influence on our treatment of fractures.

There is an old saying, "Hard words break no bones", nor when bones are broken do soft words mend them! For they require something more dynamic than a good bedside manner. Yet there is danger inherent in the mechanical efficiency of our modern methods; danger lest the craftsman forget that union cannot be imposed but may have to be encouraged! For a bone is a plant with its roots in the soft tissues and, when its vascular connections are damaged, it often requires not the technique of a cabinet-maker but the patient care of a gardener.

Today I propose to discuss three forms which the ischaemia may take, and to indicate how vital is the right choice of treatment. There is one form which we shall call "traumatic arterial ischaemia" because it originates from damage to the arterial supply of one or both fragments at the time of the fracture. Though this form of ischaemia is much commoner than Volkmann's, comparatively little attention has been paid to it; and this is particularly unfortunate because whenever it occurs, and is unrecognized, the delay in union which follows appears inexplicable, and the line of treatment which seems right is likely to prove wrong! Later will come the story of a very remarkable case which drove this home to me by a series of bitter blows.

First, then, let me briefly review the secondary and, in the main, avoidable ischaemias.

A. SECONDARY ISCHAEMIA

Here the ischaemia is not the direct result of the injury, but arises subsequently. There are two forms:

1. Volkmann's Ischaemic Contracture, the Result of Sudden Localized Pressure

This tragedy needs no detailed description here. As a result of the ischaemia the highly specialized and delicate muscle cells die and are re-

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placed by fibrous tissue. All the uncertainties which made it so formidable have, in recent years, been cleared away, and, now that we understand its causation, we can (almost always) prevent its development. The essential factor is blockage of the venous return by rapidly increasing pressure, but in the elbow this is often complicated by damage to the brachial artery and median nerve. The pressure may arise within, or be applied from without; common factors are tight bandaging, splint pressure, flexion in the presence of swelling, or imperfect reduction, and a subfascial hematoma.

The latter is of special importance as a subfascial hematoma can produce ischaemic contracture without external compression, without flexion above ninety degrees, and even without a fracture. There are unmistakable warnings which must be looked for and relieved without delay. And this is a matter of great urgency, for a case has been recorded in which a surgeon reduced the fracture at the beginning of his list of operations, but when he saw the patient again in the ward at the end of his list, four hours later, permanent damage had been done. This was before the mechanism was understood, and I believe that watchfulness and immediate relief of venous back pressure, as soon as it is manifest, will insure the survival of the delicate neuromuscular tissues.

The following is an illustrative case:

A girl of seven fell from a pony and sustained a supracondylar fracture of the humerus. When seen five hours later, the whole region of the elbow was tensely swollen. The veins of the hand were distended. The ischaemia was venous, for, with the elbow at 120 degrees, the radial pulse could be detected, but it was very small and was promptly obliterated by flexion above ninety degrees.

It was felt that the tense swelling of the part would make reduction dangerous to attempt, and, if achieved, impossible to control. It appeared wise first to relieve the compression, then, a few days later, to reduce the fracture when the vascular state of the arm was safe and the elbow could be flexed enough to maintain reduction. An anaesthetic was given and three openings were made through the deep fascia. Though no great amount of extravasated blood escaped, the pressure was relieved (and that has been my experience in the three cases I have dealt with). The fracture was gently manipulated into better position, but, as there was still much general swelling, the arm was left supported well below a right angle.

Roentgenograms taken a few days later showed that there was still some displacement. Operative reduction was then recommended as a more delicate, accurate, and therefore safer method than manipulation. Another opinion was sought, the same advice given, and open reduction carried out with a good result.

In such cases, and whenever reduction has been previously and unsuccessfully attempted under anaesthesia, open reduction rather than further manipulation is advocated. In view of the danger to vessels and nerves, it is preferable to approach the fracture from the antero-internal aspect and to begin by identifying the brachial artery and median nerve, tracing them down to their perilous position on the jutting edge of the upper fragment. Once they are freed and protected, reduction is easy and safe.

2. An Ischaemia Due to Relatively Prolonged and Widespread Constriction and Disuse

This is followed by a condition which has been called traumatic osteoporosis; but I regard that title as misleading in that the changes, at least in the cases which it has been my privilege to see, are by no means confined to the bones. This condition is included today because I believe it to be a sympathetic dysfunction secondary to an ischaemia, provoked by compression, and prolonged by disuse, during which all the normal afferent sympathetic stimuli are abolished. It affects most commonly the forearm and hand of patients past middle life. The distal parts are swollen and cool; the skin is smooth and of a dusky red color. There is pain and great impairment of active and passive movements. Roentgenograms show a characteristic, widespread, and extreme decalcification with osteoporosis. Köhler speaks of this type of bone atrophy as indicating an acute inflammatory change. But surely it is not inflammatory! It appears rather to be a severe disturbance of sympathetic function.

Three conditions usually combine to produce this distressing condition,—middle life, firm bandaging, and immobility of the hand, either imposed or assumed.

Diagnosis

In its established state this is obvious. But safety lies in the avoidance of its causes, and a second chance is given by recognition of its early signs and symptoms. These are illustrated in the following case:

An elderly lady was brought to me with a comminuted Colles' fracture only one hour old. Under local anaesthesia the fracture was reduced and the accuracy of reduction confirmed by roentgenograms. The wrist was put up in plaster, including the forearm and the carpus, but leaving the hand free. She was given a sling and the most strict and explicit instructions to let her doctor (or me) know immediately if she had pain, or any swelling, blueness, pallor, or coldness of the hand. This was in the morning and she was comfortable all day, but, after she went to bed, the part became painful. Unfortunately, "she didn't want to worry" either of us! The pain kept her awake and in the morning she sent an urgent message to her doctor, which somehow in transit lost all its urgency. So the doctor did not call until late in the morning and it was nearly one o'clock before I saw her. By that time the circulation of the lower forearm had been constricted for fourteen hours. The hand was cool and rather dusky, with some dulling of sensation and impairment of intrinsic action. From the subsequent appearance it was clear that the swelling inside the plaster had been due to extensive extravasation of blood. Fortunately, she did well, but for some weeks had a good deal of pain and a mild degree of the sympathetic dysfunction which has been described.

This case has convinced me that it is unsafe, except when the patient is under skilled nursing supervision, to apply any unyielding splintage to a limb within a few hours of a fracture. The surgeon cannot foretell the amount of swelling which will later take place; nor is it easy for the patient to know how much discomfort she should expect and at what point she should send for help.

B. TRAUMATIC ARTERIAL ISCHAEMIA OF ONE OR BOTH FRAGMENTS

There is one well recognized form of which I can quickly dispose,—*viz.*, an intra-articular fracture in which there is complete or almost complete devascularization of the small fragment. Common examples are most fractures of the carpal scaphoid and some of the femoral neck; probably the so called osteochondritis dissecans should be included, but that is a by-way we must avoid today. The devascularization of these fragments is made evident in subsequent roentgenograms in that they do not share in the surrounding decalcification. And the treatment of such fractures is to hold the fractured surfaces in contact, accurately and uninterruptedly immobilized, until the free fragment has been revascularized by the growth of vessels from its better half—however long it takes! The progress and ultimate completion of this change is shown by the advancing equalization of the density of the two fragments. But in the hip, as Phemister has pointed out, revascularization is not enough; further patience and protection are required, for weight-bearing is only safe after the young bone has become retrabeculated. In the carpal scaphoid, even if bony union does not occur, painless function generally follows, provided that due patience has been exercised, and that means six months or more of continuous immobilization of the wrist in full dorsiflexion with natural use of the hand.

I am, however, mainly concerned with ischaemia in fractures of the shafts of the long bones. The admirable experiments of Johnson[1] have demonstrated the share taken by the nutrient, periosteal, and metaphyseal vessels in maintaining the blood supply of the shaft. Though in bone the establishment of anastomotic circulation is always relatively slow, yet Johnson's experiments showed that, after the nutrient artery had been avulsed or severely damaged, the endosteal circulation was reestablished in a few weeks, and that in the meantime the whole bone remained alive. But our clinical experiences are less happy, probably because a healthy young dog compares favorably with an underexercised, overclothed, and otherwise pampered man. Phemister[2] indeed speaks of aseptic necrosis as occurring in shaft fractures, but as a temporary almost transitory state, and being dealt with rapidly by "creeping substitution". I believe this to be a common cause of delayed union and of non-union. And I prefer to call the condition "ischaemia" as a term which includes all degrees of defective circulation. For their ordinary day-to-day duties the cells in a bone are provided with an adequate supply of blood. Any diminution tends to subdue their activities, and, in accordance with the degree of ischaemia, the cells pass from quiescence to suspended animation or even death. The union of a fracture is between three parts,—fragment, callus, fragment. So long as either fragment remains short of blood, union is delayed. For the exceptionally heavy task of union, the cells require a plentiful blood supply for function and circulation balance.

Now delayed union due to ischaemia may bring one up against great difficulties: prolonged immobilization without function is a negative

policy, like wrapping one's talent in a napkin and burying it when interest is most needed; on the other hand, function may present difficulties of splintage and the patient may grow restive. Because of these obstacles, the attractions of operative interference may become almost irresistible. Operations, however, in the presence of ischaemia are futile and worse than futile. May I quote an illustration in sack-cloth and ashes?

In July 1928 a very healthy and athletic young man of twenty-two years of age and weighing 200 pounds, while riding a motorcycle, was struck with great force in the mid-thigh by the mudguard of a lorry. Seven weeks later, despite the maintenance of good apposition on a Thomas splint, there was no sign of union nor of callus. I operated and found the ends in apposition, but each was capped with gray, avascular fibrous tissue without any organized link between them. The fracture was grafted, by Albee's method, from the tibia and a plate, made of bone, was applied. The limb was kept on a Thomas splint, but some weeks later both graft and plate broke across at the site of fracture and at the end of seventeen weeks there was no sign of union nor of callus. The patient was gotten up in a walking caliper with a plaster bucket to control the fragments as accurately as possible.

Twenty-five weeks after the fracture, there was still no sign of union, though some periosteal callus had just begun to appear on the upper fragment some two inches *above* the site of fracture. The victim was getting restless and I thought that a very strong graft would offer a prospect of union. I was careful to avoid any unnecessary exposure of bone in order to preserve its vascular connections. I found perfect bone-to-bone contact without intervening fibrosis or synovialization, but *no callus*. I fixed a massive graft, seven inches long, firmly into place and put the limb back on a Thomas splint with ice-tong extension.

Ten weeks later, the graft broke across at the site of the fracture and all sign of the callus, even at a distance, had disappeared. For reasons which at the time appeared sound, I operated again, finding the ends still in perfect apposition, but white and avascular. I applied a very massive graft and two plates made of bone, one on the inner and one on the outer side.

Six weeks later, there was no sign of callus; so again I got the patient up in a walking caliper. The victim and I were now resigned to patience!

Eight months later—*i. e.*, one year and seven months after the fracture—some callus was appearing, but only on the inner side and behind. At this point I put in osteoperiosteal grafts on the outer and anterior aspects, and in twenty-two months after the fracture the femur had at last united.

Then came restoration of movement to a very stiff knee, and this was an extremely tough job, involving extensive tenotomy of fibrosed, extracapsular structures. But now all is well.

In March 1931 he was playing hockey and wrote the other day, "The leg I am glad to say is marvelous. . . . I hardly notice the difference in the two."

The traumatic arterial ischaemia in this case was extreme and extraordinarily persistent, but I feel responsible for its prolongation. Once the bone ends had been exposed at my first operation and the bloodless state of both fragments thereby discovered, I had the essential information and rightly got the patient up in a walking appliance, but he should have been kept in it much longer. Had it been possible to prevent outward angulation of the femur, I should unquestionably have done so. The patient, however, was very heavy and muscular, and, though the end-to-end apposition remained perfect from the first operation onward,

whenever powerful extension was removed the femur angulated outward, snapping strong grafts and bone plates like twigs. Viewed in retrospect, he should have been kept in a walking caliper, angulation or no, until the appearance of callus in connection with both ends proved that the ischaemia was over. The operations in the middle period were useless and must have deferred the establishment of a normal sympathetic reflex syndrome. That the patient and I reached a good result together was due to his loyalty! But he had been subjected to a series of difficult and serious operations, of which at least two might have been avoided!

Such a case as this makes one think hard and painfully and the experiments of Johnson[1] give one a standard. I am driven to the conclusion that in order to explain such persistent avascularity of part of the shaft of a long bone we must deduce a dysfunction of the local sympathetic system. Therefore, the following etiological description of traumatic arterial ischaemia is suggested:

A. Origin, damage to the arterial supply of one or both fragments.
B. Secondary factors capable of aggravating or prolonging the schaemia.
   1. Circumferential compression.
   2. Powerful traction applied rapidly, tending to strangulate the bruised and infiltrated tissues in the neighborhood of the fracture, through which tissues the reestablishment of the circulation around the ends of the fragments is normally brought about.
   3. Total disuse of the limb, with abolition of all the natural vasodilatory, afferent impulses which are associated with function.
   4. Further traumata such as premature and repeated operations.

Diagnosis

One may suspect arterial ischaemia from the site of the fracture or the absence of any interfragmental hematoma. And if some weeks later, despite good apposition of the fragments, there is no union and no sign of callus, a tentative diagnosis of ischaemia can be made.

TREATMENT

1. Patience. The gardener does not dig up his plants to see how their roots are doing! Even manual examination may damage the delicate young vascular connections, and premature operations are not only worthless, but tire the patient and add further trauma. I suggest that the persistence of ischaemia in cases such as have been described implies a dysfunction of the local sympathetic system and that operations aggravate this dysfunction, in addition to deferring the corrective influence of natural function.

2. Continuous, accurate immobilization without constriction. This should interfere as little as possible with the movement and function of

the neighboring parts. Lateral mobility must be avoided for it stimulates the fibroblasts in the neighborhood, and the fibroblasts in these cases have a dangerous majority over the osteocytes on account of the absence of any contribution of cells from the fragments; or if one speaks, in the fashion of the moment, of the region as populated by histiocytes, lateral movement tends to make them behave like fibroblasts rather than osteoblasts, producing fibrous tissue rather than bone.

3. The third remedy is function—of the whole limb and of the bone itself.

   a. Activity, sensory and motor, of as much of the limb as possible, directed toward the initiation of afferent, sympathetic impulses, and thus toward active hyperaemia through the local and ganglionic reflex arcs. This active hyperaemia is a physiolcgical response to stimuli of a physiological order.

   b. Function of the bone itself,—*e. g.*, either in an active form (weight-bearing), or in a passive form, in which vibration is applied by a hammer (H. O. Thomas), or by a vibro-massage machine. For vibration is the natural stimulus which makes bone cells work.

In addition, there is much clinical and experimental proof of the value of periodic, mild, venous congestion,[3] though continuous venous congestion appears to delay or check osteogenesis.[4]

The moral of my story is that, in dealing with any and every fracture, we should remember the vital importance of the circulation. In reduction any disentanglement should be carried out with the vascular anatomy in mind, and when axial extension is advisable the pull should be increased gradually to avoid strangulation. After reduction we have to solve this problem: How to maintain accurately the position of the fragments without any constriction of the circulation, but with the splintage so well fitted that there is a minimum of interference with the function of the limb. It is an old saying in the trade that we must make the limb fit the splint, in the sense that the splint must be the master. But we can only do so rightly and safely if we begin by making the splint fit the limb as we wish it to be. Then the hold need not be extensive, the hand can be freely used, the foot given movement or weight-bearing. Function should be reasonably easy and not uncomfortable. The uninjured parts of the limb can hardly be used too soon, but the injured parts need a period of repose. From all the tissues used comfortably and naturally will arise afferent impulses promoting hyperaemia, and there will be transmitted to the bone stimuli of the order which will activate rather than overload the osteoblasts. For we know that, *ceteris paribus*, function and blood supply balance, that there is a local control of circulation, partly through ganglionic, and partly through forked nerve-axon, reflexes; and we know that bone cells can build or unbuild, changes of environment provoking a characteristic response from cells whose hereditary and life-long craft has been the care of bone. It is for us to see that the cells are stimulated to-

ward osteogenetic activity, and that the activity is maintained by circulation which is generous in quantity and in quality.

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SUMMARY OF DISCUSSION

Dr. D. B. Phemister, Chicago, Illinois, has not been impressed with devascularization as the cause of non-union in simple fractures, though experimentally it has been recognized microscopically. Operations on ununited fractures, previously treated, have shown necrosis related to the non-union, and a case is cited in which a section of the femur one and one-half inches long was found in such a condition at operation. In the femoral head, and elsewhere, aseptic necrosis does occur and is an important factor in delayed or non-union. In the x-ray increased density of the necrotic femoral head should receive recognition.

Dr. Fred H. Albee, New York, is a believer in the importance of devascularization in non-union and has always advocated care at operation to avoid interference with blood supply and measures to increase it where possible. With these objects in view, he advises the inlay graft, long enough to contact with well vascularized tissues, fitted with a cabinet-maker's nicety, and secured by kangaroo tendon. Immobilization is required for at least eight weeks; weight-bearing should be allowed only after union has been proven by physical and x-ray examination.

Dr. W. E. Gallie, Toronto, agrees that fractures at the elbow should not be put up in acute flexion until swelling has ceased. In the matter of aseptic necrosis he is in agreement with Mr. Girdlestone and Dr. Phemister, though he feels that the presence of such necrosis is no bar to the introduction of a bone graft.

Mr. Girdlestone, closing the discussion, thinks it logical to expect aseptic necrosis in the human since it has been demonstrated experimentally in dogs. He thinks persistence of necrosis in one and one-half inches of bone, in Dr. Phemister's case, five months after operation, could be explained only on sympathetic dysfunction. He believes we must discriminate between sclerosing and non-sclerosing bone in which there is dysfunction of the vasomotor system.

THE RELATION OF THE ABDOMINAL MUSCLES TO PARALYTIC SCOLIOSIS *

BY C. L. LOWMAN, M.D., F.A.C.S., LOS ANGELES, CALIFORNIA

The loss of the integrity of the abdominal musculature is fraught with serious consequences to the harmonious function of the body as a whole, and is far more serious than has been appreciated heretofore, if one can judge by the meagerness of consideration given it in the literature, the paucity of comment by teachers, and the lack of surgical consideration of its structural aspects by general and orthopaedic surgeons.

Lange, of Munich, in his article on American and German Orthopaedic Surgery, in *The Journal of Bone and Joint Surgery* for July, 1931, (*XIII*, 479), makes the following observation:

"When scoliosis is present, due to a paralysis of the erector trunci muscles, in America correction by the Hibbs fusion operation is often attempted. In Germany we use only supporting braces and exercises. An operative method for overcoming paralysis of the abdominal muscles (though much to be desired) has, so far as I know, not been attempted."

It is my purpose to call attention to efforts we had made to meet such a situation, and demonstrate that plastic repair of the abdominal wall, other than what is used for hernial defects, is possible and a larger field of usefulness is open to exploration and development.

It is unnecessary to more than mention the very extensive literature on the subject of fascial transplants. The experimental work of Gallie, Le Mesurier, and their coworkers, of McNealy, Andrews, Pitzman, Haas, Koontz, as well as the surgical work of many other exponents of the practical use of fascia in repair of structural defects, is well known.

A thorough search made in the libraries of the American College of Surgeons and of the American Medical Association resulted in finding many references to the repair of abdominal wall defects, but none specifically relating to the subject here presented.

In 1924 we had occasion to treat a very sturdy young country girl for acute poliomyelitis, which involved chiefly her shoulder-girdle region, with the upper abdominal wall group, recti, and obliques. We recorded the possibility of scoliosis developing in the dorsal region, and knew that it would, in consequence of the location, be very difficult to combat.

This girl was kept in recumbency for months, and not allowed up, even afterward, without a carefully fitted back brace. Despite definitely graded, pool and other muscle-reeducation treatments she continued to develop scoliosis. Other factors of health were negligible; cooperation by parents was 100 per cent; no time was ever lost nor treatments interrupted, but curvature began before the erect position was allowed. Constant study and observation led us to conclude that the interference with proper

* Presented at the Annual Meeting of the American Orthopaedic Association, Toronto, June 17, 1932.

abdominal muscle function was in some way contributory to the scoliotic condition. It was also presumed that the flexors of the left thigh were weak because, even two years after the initial attack, she could only raise the extended leg two or three times before fatigue and cramp would intervene.

About a year later a young lady of sixteen, who had had two operations on the legs and feet, was found to have been made brace-free, with fairly good stability, but had a peculiar jerking hitch in her gait, which we found was apparently due to weak abdominal muscles. One day she was asked to walk for us with the abdomen exposed, and as we surmised, the umbilicus shifted its position as tension was made on the abdominal muscles. This (Beevor's sign) showed more markedly at every step and signified paralysis of a portion of the muscular wall. Every effort at moving the leg to make a step caused the umbilicus to be pulled upward and to one side. We noted also that when either leg was lifted the pelvic tilt increased, first to one side and then to the other, giving a twisting effect to the pelvic region, which accounted for the jerk in her gait.

Prolonged observation spurred our interest in making an effort to capture the remaining power in the partially paralyzed recti and obliques, when we observed the useless and ineffectual efforts of the remaining stable portion to transmit any force suitable, or sufficient, to obtain fixation of the front of the pelvis on the thorax. In our charting of the abdominal muscle strengths, we had previously been recording only the rectus anteriorly, quadratus lumborum laterally, and the obliques. Even then there seemed to be much question in the mind of the technician recording the tests as to what their real status was.

During a survey of scoliosis cases, conducted by Dr. Robert Carroll and myself, at the Orthopaedic Hospital in Los Angeles, we began to hunt for possible causes of scoliosis. We were strongly impressed by the probability that many were due to undiagnosed poliomyelitis, especially with those in whom obscure trunk muscle groups might have been partially weakened. For the previous three or four years, as cited above, my attention had been directed to the possible relationship of abdominal muscle involvement to spinal deviations. Consequently, we began at once to investigate all scoliotics not diagnosed as paralytic, for the existence of this phenomenon.

Finally, one severe paralytic scoliotic, for whom we had done seven operations over a period of ten years, and who could walk only with the aid of crutches, spine and leg braces, stated that she was willing and glad to have her abdominal defect repaired, which we did on July 17, 1931.

The operation consisted in opening the mid-line from two inches above the umbilicus to the symphysis, lateral dissection to uncover the rectus aponeurosis on the right side, which was opened and reflected, showing the attenuated remains of the paralyzed lower half of this muscle. A strip of fascia lata, obtained by another operator, was transplanted, extending from the lower two inches of the healthy upper rectus to the symphysis, into which it was inserted through an osteoperiosteal slot

raised from the bone. The strip, one inch wide and nine inches long, was sutured with silk above for two inches, then, with the operating table dipped in the middle to slacken the pull on the abdominal wall, the umbilical stem was grasped in strong forceps and pulled downward as far as possible, while the lower end of the strip was forced into the osteoperiosteal slot below and firmly sutured with silk. Sutures of silk were similarly placed on each side at intervals of an inch to an inch and a half; then the aponeurosis was laid back and stitched down with chromic catgut. Before further closing, another strip was fastened to the same location above and passed subcutaneously in the fat, downward and outward, to the right ilium at the point of attachment of Poupart's ligament, and attached osteoperiosteally as before, after all the slack, which would be allowed by the shortened upper left oblique, was taken up.

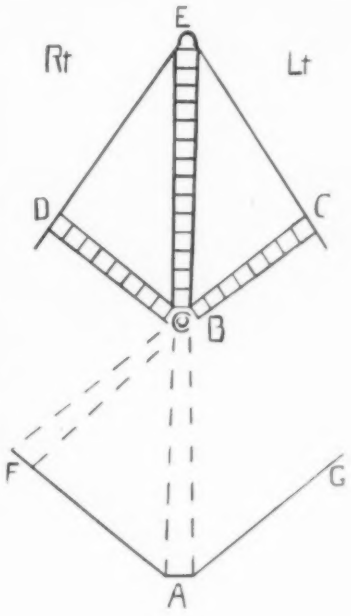

FIG. 1

Operation plan of first case, A. D., (See Fig. 2). Severe scoliosis in right lumbar region with pelvic droop on right.

This patient whose case was reported in the *New England Journal of Medicine* for December 17, 1931 (CCV, 1187), can now, almost a year after operation, stand without crutches for the first time in nine years, and is beginning to take steps without them.

The first case mentioned above was the second patient operated upon, and in her case the strips were put in from below upward. The upper rectus being the weak section, one strip went straight up to the rib margin and the other went outward to the opposite right costal border lower down, forming a Y attachment.

Referring to Figure 1, the diagram shows that the pull from point *E* to *B* will be transmitted through the new tendons to *A* and *F*, being split at *B*. Likewise the pulls of the upper oblique from *D*, and especially from *C*, will also transmit power via *B* to *F* and *A*.

In the second plan, the pull of the healthy lower rectus (Fig. 3) and the obliques will be transmitted through the new transplants from *A* to *D* and *E*, and slightly to *C*, via the weak remains of the upper left obliquus, while the strong oblique pull from *C* will also activate *BD* and *BE*, assisted somewhat by the force from both *AB* and *FB*.

As an illustration of the importance of the fixing and stabilizing effect of the abdominal muscles, these cases showed an immediate postoperative obliteration of Beevor's sign (*i.e.*, no movement of the navel, on head raising from the supine position).

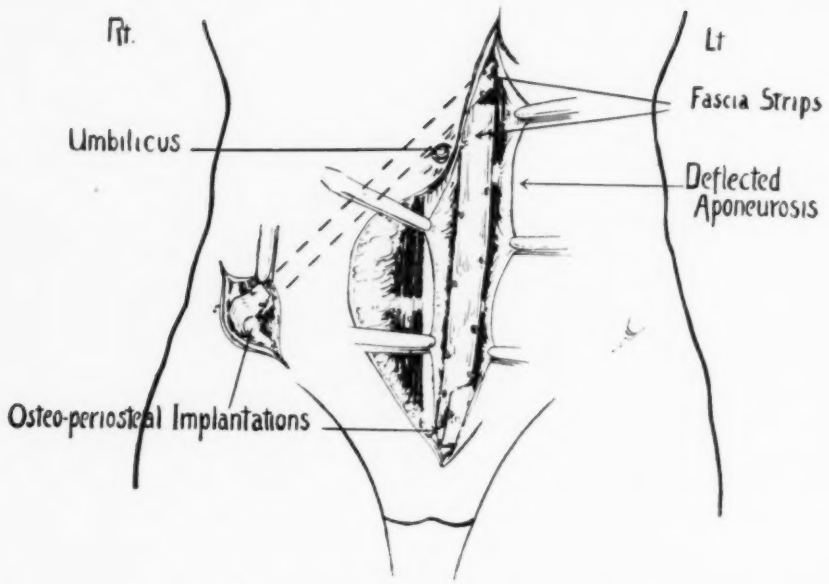

FIG. 2

Artist's sketch of first operation. Patient A. D.: paralysis of lower recti and right obliques. Fascial strip in sheath of left rectus and subcutaneous strip as fixation for healthy upper right oblique.

Case 2 further showed this stabilizing effect, by the fact that the weakness of leg raising disappeared. What we had supposed was weakness in the thigh flexors was actually not intrinsic psoas weakness, but weakness of the extrinsic stabilizers of the pelvis necessary for the proper action of the leg flexors at the hip joint.

We are quite convinced that asymmetrical influences of faulty kinetics do affect the spinal column in several ways, notably as follows:

1. Involved and relaxed rectus abdominis tends to produce forward tilt of the pelvis and lordosis of the low back, made worse when thigh flexors are active.

2. Unbalanced action of the quadratus lumborum induces lateral deviation in the lumbosacral region with secondary compensatory changes above. The latissimus dorsi may be similarly affected.

3. The transversalis, when strong and active on the one side and not balanced by its fellow on the opposite side, affects the lumbar section, and, in conjunction with quadratus imbalance, produces curvature and probably also rotation-deviation because of the pull on the lateral processes.

4. We feel that the presence of imbalances in the abdominal obliques, which are the stabilizers of the rib cage toward the mid-line, allows the rib cage to swing laterally until a point of fixation is reached, whenever arm and shoulder-girdle movements or leg and pelvic movements are made and thus, especially with asymmetrical influences, such as right-handedness and one-sided pull of the diaphragm (as noted by Jansen), a

rotary spinal deviation will be produced.

5. Whenever the serratus magnus is activated, as in forward pushing and reaching, it pulls upon its origin which, it will be recalled, is along the anterior rib margin where it interdigitates with the abdominal obliques. This pull, in the presence of droop shoulders and weakened rhomboids, plus the assistance of the pectoralis major, holds the weight of the shoulder, arm, and breast against the thoracic wall anterior to the angle of the ribs, and has a flattening effect on the side of the chest wall.

As the pull of the serratus is from in front and below, upward and backward around the side, it must of necessity have some stabilizer in order to be effective,—*i. e.*, the thorax must be fixed at the point of origin where the force applied will move the base of action instead of the shoulder. The chief opponents of this pull are the abdominal obliques and opposite transversalis. The rib margin is stabilized against side twisting by the broad upper obliques which insert into the rectus aponeurosis and the linea alba, and this structure is fixed by the opposite lower obliques and transversalis to the opposite ilium.

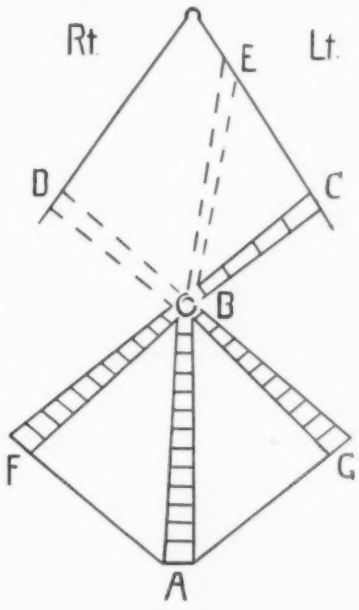

FIG. 3

Operation plan of second case, E. C. Strip *EB* within upper left sheath. Osteoperiosteal insertion through two split rib margins. Strip *DB* subcutaneous stabilizer for right serratus and lower left oblique and transversalis. Progressive right dorsal scoliosis starting during recumbency period.

If the integrity of this diagonal pull is interfered with, the rib cage will swing laterally under the pull, until some point of fixation is reached. Now if the upper or lower half of the rectus abdominis is paretic or paralyzed, or if the upper oblique on one side, or the lower oblique on the opposite, is likewise involved, either or all of them, separately or together, the stabilization of the rib cage on the pelvis cannot be attained. In consequence, unopposed muscles with diagonal or lateral pulls, like the transversalis, serratus magnus, abdominal obliques, together with asymmetrical action of the unbalanced pull exerted by the pectorals, especially the minor, latissimus dorsi and quadratus lumborum will contribute materially to spinal and costal deformation.

The chief factors in the production of scoliosis, other than hereditary congenital faults, are:

1. Gravity pull.
2. Skeletal asymmetries, such as short leg, or pelvic discrepancies of development.
3. Structural alteration of muscle action.

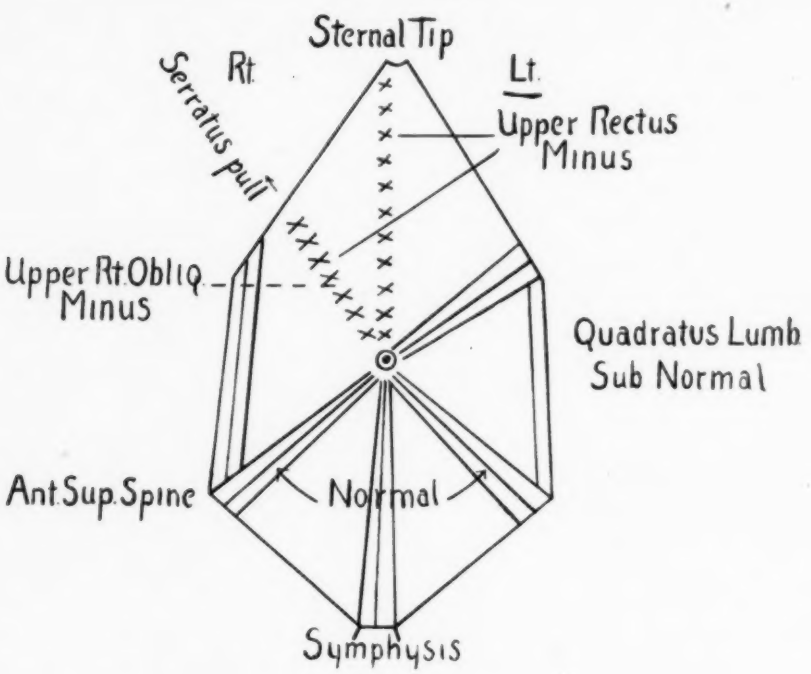

FIG. 4

Muscle chart, preoperative record of second case operated upon, E. C. ||| = normal. || = moderately active. | = active but weak. xxx = inactive. (See Fig. 3.)

In all cases some degree of each of these causative factors exists, but in paralytic scoliosis in the growing child, the last mentioned is usually the initial cause, which allows the force of gravity, acting in a wrong direction, to influence the skeleton, and then the second factor becomes more and more an influence as asymmetries of skeletal growth occur.

Due to the fact that we have seen both lateral and rotary spinal deviation initiated in children previously straight, during the stage of recumbent treatment following an attack of poliomyelitis, in which instance gravity pull can be ruled out, as can also be growth faults, which are only an influence in sitting or in the erect position, we must conclude that the unbalanced action of unopposed muscle pulls is the factor which, in many instances, initiates the deformity. For instance, in a boy five years of age, previously straight, a curvature is developed, even though he was recumbent for a year, and the only affected muscles were the upper half of the abdominal muscles and a moderate involvement of the shoulder girdle.

This same condition existed in the first case mentioned in this paper, an older child, in which instance, the condition progressed despite recumbency over a long period, braces, traction, casts, etc. under the best conditions of cooperation and skilfull treatment (See Figure 3).

The rotary deformity is particularly influenced by the unbalanced action of the serratus when its extrinsic fixators are involved. Right-

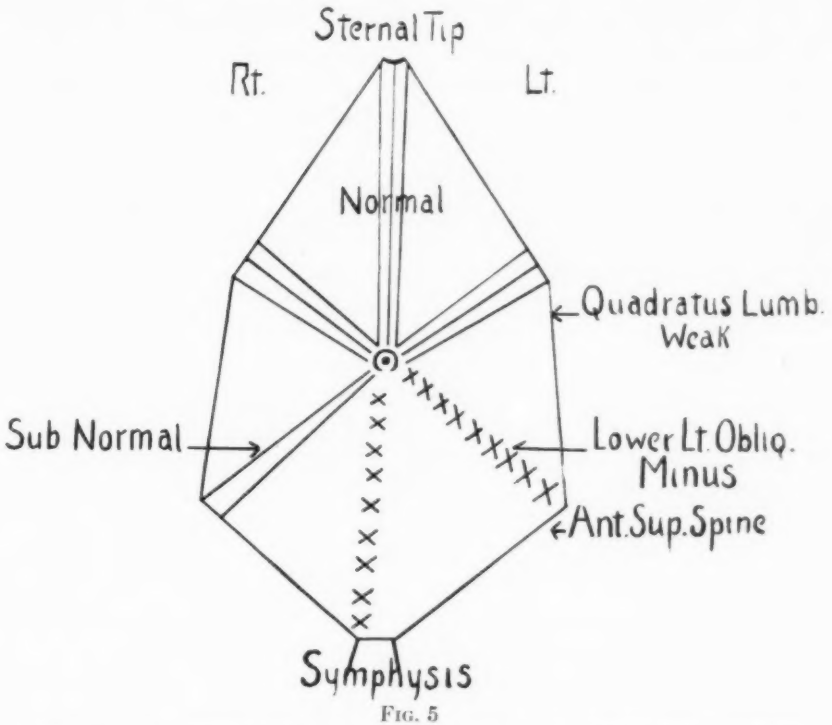

FIG. 5

Diagrammatic muscle check, postoperative, of G. E., fourth case. Marked lower trunk weakness, absent lower left obliques and lower half recti. Only slight scoliosis.

handedness, plus the continuous asymmetrical action of the diaphragm in breathing (if we accept Jansen's observations in this connection), plus these other factors which become effective as soon as the upright position is assumed, must be regarded as contributory.

We have found, upon close observation suggested by this study, that our previous tests of the strength and integrity of the abdominal musculature were too limited to show up the actual conditions which exist in such cases. Consequently, in testing, we have discovered the following movements useful in determining the presence of involvement of the abdominal wall, and the presence of its weakness or paralysis:

1. a. Raising the head forward from supine position.

b. Raising head forward against resistance to forehead,—a test of the recti, chiefly.

2. Straight arm push from recumbent position forward from shoulder against resistance, noting the action of obliques, to test serratus magnus.

3. a. Leg raising, each side without, or with, assistance.

b. Against moderate resistance. This tests obliques and rectus in relation to hip flexors.

4. Leg pull up, or hip raising against resistance. This tests quadratus lumborum and, somewhat, the latissimus dorsi.

5. Starting to roll over. This tests transversalis and obliques in relation to mid-line stability of rectus or opposite muscles.

6. a. In the water, prone and supine "jack-knife" exercises,—*i. e.*, lying supine, sinking the hips and bringing shoulders and knees toward each other.

b. Prone, sinking the shoulders and knees and raising pelvis out of the water. For positive findings one will note the presence in varying degrees of the umbilical movement sign, with its displacement toward the strongest muscles. In the presence of total paralysis, or normal muscles, there will be no movement of the navel.

7. Another test is also used to note the area of weakness. The patient takes a big breath, presses down on the diaphragm and tries to balloon the abdomen. In total paralysis it can be greatly distended without any feeling of muscular resistance to the palpating hand; or, if limited areas are weakened, they will protrude to a greater distance than the surrounding area and there will be diminished resistance of the wall over the region affected.

8. For localizing action of opposite obliques, a good test is as follows: supine lying in water, arms extended upward in form of a Y, legs half abducted, the opposite arm and leg are raised. This tends to twist the body and is a pure test of oblique fixation.

We have noted some cases of scoliosis of the structural type, previously undiagnosed as to cause, to show this phenomenon, as well as a positive umbilical sign, when there was nothing in the history to lead one to suspect a paralytic origin. The importance of such differential diagnosis lies in the fact that the progress is graver and the treatment more difficult in the paralytic cases.

Whether or not this plastic repair of the abdominal wall will have a corrective influence on scoliosis after the other factors are added, we cannot as yet say. However, we feel justified in reasoning that a scoliosis with rotation-deviation occurring in a straight child, during convalescence in recumbency, and in whom partial paralysis of some sections of the abdominal musculature is the most notable involvement, must have local muscular paresis as a causative or contributory influence through muscle imbalance.

If we wait until curvature develops and then fuse the column we will in no way alter the kinesiological imbalance of these important muscles. On the other hand, since repair of the defect has greatly improved even some old chronic scoliotic cases, we feel certain that its early repair will give much help to the early ones and will probably have a decidedly preventive influence on the deforming forces. We also feel that early recapture of the wasted power of the remaining viable portions of the muscles, by the means described, may greatly aid in preventing the advance of the condition to as extreme a degree as it might otherwise progress.

The procedure is somewhat tedious but in no way technically difficult; it requires no great depth of anaesthesia and is attended by little

danger to the patient. The postoperative treatment is simple, needing only a semirecumbent position in bed for three weeks, after which sitting in a wheel chair may be allowed. Early movements in the water give an excellent method of beginning reeducation to the muscles and put physiological strain on the new tendons without gravity load. They are begun as early as twenty-one to twenty-four days and continued, with gradually increased load, until all danger is passed. Walking in deep water is begun at four to five weeks, and then walking as before.

Twelve cases have been operated upon to date, some too recent to record, but our physiotherapists report all progressing satisfactorily. Those done more than six months ago, however, show increasing power and apparently heavy, palpable cord-like development of the fascial tendon, with a much greater sense of the support to the abdominal organs. They all seem improved in general, out of proportion to the local benefit anticipated. This general improvement may readily be due to added support given the abdominal contents and from preventing visceral drag on vessels and nerves. The first patient operated upon has recently stated that she feels more benefit from this procedure than from any of her previous eight operations. Her father, who is a physician, stated that she can sit longer without fatigue, handle her body with greater facility, and shows a renewed interest in everything being done for her. She has begun to take steps without crutches for the first time since she was stricken nine years ago. We have, in the case of girls, placed these fascial strips only from the umbilicus up or down with the idea that ultimately they would be no obstacle to pregnancy. However, in two cases, one done in January and the other in April, 1932, one boy and one girl, with severe lateral lists of the trunk on the pelvis, strips were run from the iliac crests to the umbilicus on one side below and from there to the rib margin on the opposite side above, to act as diagonal tethers. The boy is now able to sit up and hold himself in mid-position without the tendency to list to the left as before the operation and walks much better. In the girl a much improved control is reported and the abdomen is more stable, although at this writing she has not as yet started to walk.

SUMMARY

1. The recapture of lost power in the presence of partial paralysis of the abdominal muscles is possible and practical.

2. Decided improvement in stabilization of trunk on pelvis is obtained.

3. There is a specific relationship between abdominal paralysis and paralytic scoliosis.

4. The corrective or the preventive possibilities of this procedure cannot as yet be definitely stated, but, if such a relationship is recognized, specific benefit of this nature ensues.

SUMMARY OF DISCUSSION

Dr. W. B. Carrell, Dallas, Texas, does not believe the work can be treated as a permanent result, but if it holds as well as it looks, it should be of benefit.

Dr. Arthur Steindler, Iowa City, Iowa, refutes the idea held by some that paralytic curvature develops only when patient is erect and that gravity is against function. Gravity is used at times to combat deforming tendencies, but rotation is a tendency it cannot control. It is common observation that, where the great rotators of the spine are lacking, curvature will develop during recumbency. Of these rotators the external oblique is one of the most important. When the serratus magnus is weak, it will rotate that side backward; while the external oblique, the dominant rotator of the abdominal muscles, will act in an opposite fashion on the same side. In spite of lack of elasticity and contractility of the fascial strip, Dr. Steindler thinks it affords a firm support between the costal arch on the paralyzed side and the opposite iliac crest.

Dr. W. E. Gallie, Toronto, concurred with both Dr. Carrell and Dr. Steindler upon the ingeniousness of Dr. Lowman's method of operating, but felt that time must elapse before it would be safe to draw any definite conclusions as to its value.

Dr. Lowman, in closing, cited three of the cases in which these principles had been followed out, one a bad case of muscular dystrophy.

CEREBRAL BIRTH INJURIES: THEIR ORTHOPAEDIC CLASSIFICATION AND SUBSEQUENT TREATMENT *

BY WINTHROP M. PHELPS, M.D., NEW HAVEN, CONNECTICUT

Professor of Orthopaedic Surgery, Yale University

The classification of cerebral birth injuries has always been made on a neurological basis. Lesions are described as occurring in various parts of the brain. The mechanism of production of these lesions has had much careful study. The remote causes have been considered and include such factors as prematurity, primiparity, icterus neonatorum, congenital syphilis, dystocia, and obstetrical difficulties. Classifications, distinguishing the actual birth-injury group from congenital anomalies of the nervous system, have been made. All of these studies have aroused the interest and cooperation of the obstetricians in an increased effort to prevent the injuries, in many cases unjustly attributed to them. Nevertheless, children continue to suffer from this type of dyskinaesia, whatever the cause, and treatment must be carried out. An exact definition of the term "cerebral birth injury" would strictly imply only an obstetrical injury, but the late results of many types of disturbance to the child during the last month of pregnancy and the first two or three weeks of life are, in many instances, identical with actual obstetrical damage. Hemorrhage in the cranial cavity, which is the most common cause of the types of dyskinaesia to be described, will produce the same picture, whether or not it is the result of actual obstetrical injury. Therefore, as the types of dyskinaesia come naturally to the orthopaedic surgeon for treatment, all being crippled in one way or another, a classification must be made, which can be used as a basis for treatment. Such a classification must be made on a functional basis, and must take into consideration the total function of the individual, rather than that of an arm or leg alone. Total function includes, of course, both mental and physical ability.

Little[1], in 1862, described these cases first in an article bearing the following title: "On the Influence of Abnormal Parturition, Difficult Labors, Premature Birth, Asphyxia Neonatorum, on the Mental and Physical Condition of the Child, Especially in Relation to Deformities". For years, Little's disease covered the whole group, of which a typical example was the feeble-minded, drooling child, with scissors gait and marked general spasticity. But further study has shown that there are many physically handicapped types, with or without mental deficiency. These individuals may often be wrongly classified as mentally deficient, because of lack of motor control of the facial muscles, or physical inability to speak or perform the usual intelligence tests. Therefore, it is important to determine the mental level in these cases as accurately as possible,

* Read before the Section of Orthopaedic Surgery, New York Academy of Medicine, January 15, 1932.

while allowing for the physical handicap. A recent survey of a large feeble-minded institution* has shown approximately six per cent. with motor disturbance and a definite history of birth injury. It is probable that actual mental deficiency is not present in some of these, but that retardation has resulted from environmental difficulties. Study of mental level evaluation in children showing physical handicaps is showing, more and more, that there is behind the mask of dyskinaesia a trainable mind in a large percentage of the birth-injured.

Confusion in late diagnosis of these conditions is certain to occur because of the many acquired physical handicaps which resemble closely, at first glance, the birth-injury group. It is not sufficient to classify these cases as "spastics" or as "Little's disease". Treatment obviously will be of no avail, even in the group in which the mentality is good, if the lesion is progressive. Many cases of epidemic encephalitis result in a physical handicap which is identical with certain types of birth injury and, if the history is not available, a differential diagnosis is difficult. However, most, if not all, of the postencephalitic group show a progressive picture and observation over a period of time will demonstrate this fact. The same is true of Wilson's disease. Confusion arises also in cases of congenital anomalies of the central nervous system, especially in regard to the diplegic group, described by Ford, Crothers, and Putnam.[2] If there is the slightest tendency toward an asymmetrical distribution, the cases are regarded as probable birth injuries, all other factors being equal. Slowly growing brain neoplasms may also occasionally be confused with birth injuries, but in these cases their progressive nature soon becomes apparent.

Having determined that the intelligence is sufficiently great to make treatment worth while, and that the lesion is static and not progressive, the exact type of dyskinaesia must be studied, in order to carry out a rational form of treatment. Originally, all cases not showing flaccid paralysis, as in poliomyelitis, were grouped as spastic. Later, it was seen that some showed a predominance of incoordination and uncontrolled movements, and the group was divided into those with spasticity and those with athetosis. Further study of the motor disturbances demonstrates that there are many varieties of dyskinaesia, which, in order to carry out rational and intelligent therapy, must be distinguished and treated as entities.

There are two chief methods of study of these disturbances. In many cases, the movements are too rapid to be caught by the eye, but the use of slow-motion pictures will reveal the difficulty exactly. The second method, which will only be mentioned at this time, is the laboratory procedure of oscillographic records of muscle-action currents. Much information can be gained concerning rate of contraction, sequence of contraction, shape of curve, etc. As a result of these two methods, definite entities become observable. These may be considered under five

*The Training School, Vineland, New Jersey.

main headings,—namely, (1) Spasticity, (2) Athetosis, (3) Overflow or Synkinaesia, (4) Incoordination or Ataxia, (5) Tremor. It is significant that these practically never appear in pure form, but rather one type will dominate the picture, with evidences of other disturbances present to a lesser degree.

1. *Spasticity.*

Spasticity represents a hyperirritability of muscle to any stimulus. Tapping on the patellar tendon produces a markedly increased violence of contraction of the quadriceps. But any stimulus will likewise produce this contraction. Clapping the hands loudly causes sudden response, or any local disturbance of the muscle, such as rubbing or striking. Stretching the muscle is, of course, a distinct stimulus to contraction. This is seen especially on attempted passive motion. The muscles seem to resist the pull, which is clearly the result of the stimulus to contraction caused by the attempted passive motion. The typical disturbance in the spastic individual is thus explained. For example, the patient voluntarily attempts to flex the knee by contracting the hamstrings. The motion of the knee in the direction of flexion tends to stretch the quadriceps extensor. This stimulus causes a contraction of the extensor reflexly. Therefore, the result is a contraction (voluntary) of the flexors, almost simultaneous with a contraction (reflex) of the extensors, resulting either in no motion at all or markedly impeded motion. This mechanism becomes obvious in the slow-motion picture. Spasticity, therefore, is dyskinaesia found in muscles which are hypersensitive to contractile stimuli and in which voluntary contraction of a given group produces reflex contraction in the antagonistic group.

2. *Athetosis.*

A study of the literature brings to light an extremely confused picture. Many use the word interchangeably with choreiform movements, incoordination, etc. An attempt to determine this condition as an entity is greatly simplified with slow-motion pictures. It is seen as an involuntary, more or less constant contraction of successive muscles, without regard to function in antagonistic or reciprocal groups. It may be rapid or slow and is not affected by voluntary contraction. When voluntary contraction is willed, it becomes superimposed on the athetoid movement, the result resembling closely other forms of incoordination. Careful observation of the films will show definitely this superimposition. Athetosis, then, can be defined as involuntary motion of unrelated muscles which produces incoordination as a result of superimposed normal voluntary contraction.

3. *Overflow or Synkinaesia.*

Overflow represents another separate entity of dyskinaesia. It is involuntary motion resulting from voluntary attempts at motion. It is an example of the difference between neurological and orthopaedic classifi-

cation. For overflow is often not a pathological neurological entity. Very little is known about it, yet it is very important therapeutically. Overflow is seen as motion of the legs or feet, on attempts at voluntary motion of the hand or arm. It is seen as involuntary motion of the hands on attempted use of the legs. The overflow may be limited to the face on use of either the arms or legs. The degree of overflow varies within wide limits. It is seen in normal individuals occasionally. Sticking out the tongue or grimacing while writing or untying knots represents a more or less normal overflow reaction. The amount of overflow usually increases with the difficulty or complexity of the motion. It may be associated, therefore, with any form of dyskinaesia. Severe facial overflow frequently causes the patient to appear feeble-minded because of the grimaces on attempts to walk or use the arms. It is misleading, especially when it results from voluntary attempts at speech, but it is more important from a therapeutic view-point when it occurs in the arms or legs and interferes with motor control.

4. *Incoordination or Ataxia.*

The term has been used to describe so many different entities that it is probably inadvisable to use it unmodified. In the discussion of athetosis, for example, it was seen that incoordination resulted from the superimposition of normal voluntary efforts upon athetotic motion. This would differ markedly from voluntary incoordination. Voluntary incoordination would be represented by the inability to direct movement in the desired direction. Again, careful observation aided by slow-motion pictures will identify this entity. It is seen in its pure form in the ataxias and is to be distinguished especially from athetosis and overflow. Incoordination, thus resulting when a voluntary effort is made to perform a given motion, may result from a variety of causes, which include loss of muscle sense, loss of equilibrium, etc., or, more rarely, interference with muscle balance of peripheral nerve or muscle origin. Passive incoordination represents such combinations of conditions as result from athetosis and voluntary effort, but can be reduced to more fundamental difficulties.

5. *Tremor.*

Tremors can be classed as fine or coarse, and as intentional or non-intentional. There is no confusion concerning this type of dyskinaesia, except in cases of very coarse intention tremor where the condition suggests an incoordination. It can be distinguished, however, by its rhythmical and recurrent nature.

The five above entities or varieties of dyskinaesia are those which are found in birth injuries or in conditions which are likely to be mistaken for birth injuries. Other varieties of disturbance of motor function are usually well defined. Chorea may be mistaken for a fairly rapid athetosis. Choreic motions are spontaneous, involuntary motions, not constant in character but presenting a much more definite pattern than athetosis.

These motions are so rapid that they often appear purposeless. If they are slowed down by means of a slow-motion picture, the pattern becomes obvious in nearly all cases. In athetosis this is not true. Habit spasms or tics are not likely to be mistaken for other conditions. Convulsions are usually unmistakable, although in severe cases of athetosis a momentary impression of a convulsion may be given. Decerebrate rigidity needs no comment here.

The five varieties of dyskinaesia described seldom occur in pure form. They are seen combined in various degrees and must be distinguished in every case. The relation to attempted voluntary motion must be carefully studied with the idea of therapy in mind. The aim of the whole orthopaedic study is to supplement the neurological diagnosis in such a way as to determine the practicability and advisability of treatment. It is for the same reason that the orthopaedic surgeon must make, or have made, a careful evaluation of the mental status. This cannot be done successfully without a clear understanding of the physical handicap, involving, as it may, the muscles of speech and face. Of course, many other factors, social and individual, must aid in determining the practicability of treatment, as many years are necessary to bring about satisfactory results and interruptions of treatment during this time frequently cause loss of all previous benefit.

Having completed the study of dyskinaesia, it is necessary, especially in older individuals, to determine the habit factor which is complicating the picture. The ability of these patients to perform their daily routine acts is sometimes extraordinary, but these acts are carried out in bizarre ways which have been stumbled on and which, when repeated, become habits. One patient with only a mild athetosis could only pick up objects from the table with his back to the table. When much younger, he had found that he could do this, and always afterward he repeated it. After a very short period of treatment, he was trained to accomplish this act in the usual way. The result was very great in his general welfare, as he could eat at a table after this and his social life consequently was much simplified.

The presence of any actual contractures must be determined. In the spastic type, apparent contractures are often mistakenly operated on. The toe-walking due to extreme spasticity of the gastrocnemius-soleus suggests contracture, but, in the examination, care and patience will prove that the foot often may be dorsiflexed the full amount. Real contractures are seen most frequently in the knees, but here again the joint may often be fully extended slowly. The adductors are often tenotomized unnecessarily, thus preventing any normal power of adduction later. The same general principles hold for the arm.

A study of the muscle balance must be made. Hyperactivity of one group as compared to another should be noted for therapeutic reasons. This is most strikingly seen in the abductor-adductor hip antagonists in the spastic group. The "scissors gait" seldom actually represents a

contracture, but the power of the adductors, being normally greater than that of the abductors, results in this position when both groups are spastic. It is, therefore, more difficult for these patients to perform abduction than adduction.

TREATMENT

1. *Relaxation. Primary Treatment.*

The principles are based on the actual difficulties found in the examination. In the spastic, the hyperirritability of muscles, resulting in almost simultaneous contraction of antagonists, is the important factor. Thus, voluntary relaxation should be one of the first aims. In the athetoid, voluntary relaxation is desirable in order to produce volitional motions later, uncomplicated by athetoid movements. The abolition of synkinaesia or overflow can only result from relaxation as a first principle. In pure incoordination, the principle of relaxation is less important, as is the case with tremors. The ability to relax is important to normal individuals. It relieves tension, mental and physical, and is essential in skilled activities. This is stressed in sport. Golfers are constantly adjured to relax. Skilled musicians must keep the body relaxed while playing. In the birth-injured, its importance is very great, and it can be taught successfully if cooperation can be obtained. In babies and youngsters, relaxation is a more normal finding and here it is taught to be maintained in the presence of more and more disturbing factors. The clap of the hands will throw many of these into spasm, but a process of conditioning will result in much benefit. In older children and adults, of course, it can be taught more directly. This part of the treatment should precede all other forms and should last until relaxation can be instituted at will and maintained at will for a long time. Aids to relaxation should be used with caution and, when used, the reason must be kept clearly in mind. Warm baths, sedatives, etc., are the chief aids. But there is great danger of bringing the patient to depend on these aids and to be unable to relax without them. The whole aim of the treatment is thus vitiated as the relaxation is obtained, but is no longer voluntary. Massage may be of help; it should be tried. In some cases the effect will be beneficial and in others it will be an irritant.

2. *Treatment of the Neck and Trunk.*

In patients who cannot stand, sit, or balance, and who have difficulty in holding up the head, general training must be started on the trunk and neck. The head can often be held up more quickly if a Thomas collar is worn for a time and muscle strengthening given daily for the neck. The collar acts to limit the extreme overstretching which results from the head falling in any direction whenever the patient is lifted. Massage and strengthening exercises of the usual type are used for the neck and back muscles, and balance is gradually attained, in the sitting position, by daily practice beginning with assistance. Often the patient will learn to balance much more quickly while wearing the Thomas collar because of

the stabilization afforded the head. The work on the extremities, most of which is done lying down, can be begun simultaneously with the strengthening of the neck and trunk.

3. *Reciprocal Motion. Treatment of the Extremities.*

Treatment should always begin with the proximal joints. A highly trained hand or foot is of no use if there is marked dyskinaesia in the shoulder or hip. The work should begin with these joints and extend gradually to the more distal parts. Often a year or more is necessary on the hips and shoulders alone, and at the end of this time very little improvement will be actually apparent. This must be stressed in the treatment, especially to relatives. The length of treatment, of course, is great,—five years usually being the minimum.

As has been seen, the inability to carry out reciprocal motion results from a variety of different causes. In spasticity, it is due to the reflex contraction of the antagonist on attempted voluntary contraction of the protagonist. In athetosis, it is due to the distortion produced by the underlying athetoid motion when a volitional motion is superimposed. In incoordination, it is due to the inability to direct the motion itself, either through loss of joint sense, as in tabes, or loss of equilibrium, as in cerebellar lesions, or through local muscle imbalance. There is less difficulty with reciprocation in overflow or in the various tremors. The reestablishment of reciprocation must depend on an understanding of the particular disturbance in the individual case.

In spasticity, the previous training in relaxation is basic. Then, while in as complete relaxation as possible, minimal passive reciprocal motion may be attempted. These motions should be of very small amplitude and be carried out very slowly, in order not to disturb the relaxation or produce reflex spasm. Later the motion should become active assisted motion. The amplitude should remain small, the rhythm be marked, and the speed of reciprocation slow. No attempt should be made to emphasize the motion in one direction more than another. Thus, if the patient is a spastic and the motion being given is abduction-adduction of the hip, the greatest pull is in the adductors, because of their greater strength. If the motion toward abduction should be emphasized, the tendency to resulting spasm in the adductors will be increased and the treatment vitiated. Therefore, the motion should be balanced in amplitude, speed, and rhythm. Some method of eliminating gravity must be used. The exercises may be given with the patient supine on a polished board, covered with talcum, or they may be given under water. Finally, active reciprocal motion may be begun by the patient himself, when it has been demonstrated that it can be done without spasm. Gradually the amplitude of motion can be increased and, much later, the speed increased. Rhythm must always be kept constant and should be equal in both directions. Passive stretching in spasticity is always entirely useless.

In athetosis, the essentials are somewhat different. Here, the athetoid movements underly essentially normal reciprocation. If the athetosis is pure, the training in reciprocation can proceed more rapidly, but the preliminary training in relaxation will be found to take a much longer time. The work is begun as passive reciprocal motion, carried through active assisted reciprocation to active reciprocation. The amplitude of the motions can be increased more rapidly than in the spastic and the rhythm must be very regular. The speed should only be increased very slowly.

In overflow or synkinaesia, the work is again different. Here, the passive reciprocal motion will be easy, as the overflow only results from attempts at active motion. The treatment, therefore, will emphasize the stage of active assisted reciprocation, and this phase will be the longest. Here, the amplitude and speed must be extremely slow, as any attempt to hurry will produce a recurrence of the difficulty.

In incoordination of the pure type, the training in reciprocation resembles closely the training for any skilled activity, as in sport. But, again, it should be begun cautiously. If joint-posture sense is absent, then there is no point in passive reciprocation, and training can be begun directly with the active phase. In cerebellar lesions, the passive phase is necessary, but of shorter duration than the assisted and active phases.

In tremors, there is very little to be accomplished when they are of the non-intention type, but, in the intention tremor, reciprocal exercise is often very effective. It should be emphasized again here that these conditions represent static lesions, the progressive ones having been eliminated, and that the attempts at controlling intention tremor are thus more successful.

The conditions described seldom occur in pure form, but one or another predominate in a given case. The reciprocal motion must be given according to the indications of all of the conditions found in the individual under treatment. Thus an athetoid patient with overflow will necessitate taking both of these conditions into consideration. Any element of spasticity seen in an otherwise athetoid patient must also be given special attention according to the principles of the treatment of spasticity. This brief summary of the use of passive, assisted, and active reciprocal motion illustrates the necessity for orthopaedic classification of these patients.

The indications for surgery should never be immediate. A period of training is often productive of surprising results, making certain operative procedures unnecessary. In any case, the procedures should be used only as incidents in, and aids to, the training program. A conservative attitude should be adopted. (a). Tenotomies are usually unnecessary as the results are irreparable. They can occasionally be used to reduce total power where one of a group is tenotomized. For example, the adductor longus, when tenotomized alone, leaves the pectineus, adductor brevis, and adductor magnus to perform the motion. A better balance may be

obtained in this way. (b). Tendon lengthening is not usually necessary or advisable, as the muscle will sooner or later contract sufficiently to produce the same deformity. However, it cannot be said that it should never be used. (c). Tendon or muscle-stripping operations are used essentially to give better contractile leverage. Thus, the Soutter operation will decrease the mechanical advantage of the rectus femoris and sartorius, and consequently increase the mechanical advantage of the hip extensors. Training in hip-extension motions may thus be facilitated. (d). Novocain injections of nerve trunks are used occasionally to determine the effect of throwing them temporarily out of function. There may be doubt occasionally about the advisability of alcohol injections or Stoffel operations. A preliminary novocain injection of the nerves in question may be of great help in this determination. (e). Alcohol injections will throw a muscle or group of muscles out of function for a period of months by the paralysis of their motor nerves. This may be desirable in order to facilitate a period of training of the antagonists so that, when power returns to the paralyzed group, a balance can be effected. (f). Stoffel operations are valuable aids to the treatment. These procedures cannot be expected to effect a cure, but, in carefully selected cases, will enable a balance of power to be brought about which results in much greater ease of training. The most common nerves used in this procedure are the branches of the obturator and of the internal or external popliteal. Of course, the procedure may be applied to the nerves of any desired muscles. (g). Sympathetic ramisection has not proven of much value. In those cases showing the "plastic rigidity" described by Hunter and Royle, it is occasionally of benefit. (h). Tendon transplantations may very occasionally help in improving balance.

4. *Advanced Treatment.*

The further treatment, when relaxation and reciprocation have been established, consists of combining motions which have been learned into action patterns. At first, it is wise to combine only two simple motions, such as hip and knee flexion, or bilateral abduction-adduction of the legs, or elbow flexion with supination. As these combinations are learned, more combinations may be added. Motion under weight-bearing gives rise to difficulties due to reflex stimulation of muscles by gravity. Thus, the motions of walking may be learned perfectly lying down and no change in the gait observed in walking. Here, the gravitational effect has not been simulated in the treatment. It can be thus simulated in the treatment by making resistance to the motions while they are being learned and the results are gratifying. The best form of record of improvement is the motion picture record, taken at definite intervals. It is impossible to remember the performance from year to year, but a comparison of films will show the rate of gain, and act as a guide to further treatment.

It may be seen, therefore, that the treatment described is not easy,

and that it covers a long period of time. It requires the careful study of the individual from all standpoints,—mental, physical, and social. The cases which are accepted for treatment require very constant care. The treatments should constitute a regular part of the daily routine and the average length of time is an hour a day. The rest of the day, the condition should be forgotten. Patients become "stale" as in too prolonged or constant training for any reason. It is advisable to skip one day a week and to allow about a month's vacation each year. Greater advances will be made by this method. The greatest gains can be made only if these patients are institutionalized. There are very few institutions at present with facilities for handling the mentally normal, birth-injured individuals. It is hoped in the future that more will incorporate these facilities and that more institutions for the care of these patients will be available.

SUMMARY

1. Cerebral birth injuries are described and the handicaps, both physical and mental, classified from an orthopaedic rather than a neurological point of view in order to facilitate therapy.

2. A neurological diagnosis is nevertheless essential in the survey of the patient in order to rule out other conditions which may be progressive.

3. A careful mental capacity evaluation must be made, taking into consideration the physical handicap as an added factor in determining the advisability of treatment.

4. Treatment is briefly outlined for the various types of dyskinaesia.

5. The use of slow-motion pictures is recommended as a great aid in distinguishing the various types of dyskinaesia encountered and as an aid in recording improvement.

6. Slow-motion pictures were shown illustrating the types described and comparative films as used for record.

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THE PNEUMOGRAPHIC METHOD OF RECORDING GAIT*†

BY R. PLATO SCHWARTZ, M.D., AND ARTHUR L. HEATH, ROCHESTER, NEW YORK

In justice to those who have been responsible for the progress of orthopaedic surgery up to the present time, we should consider its needs for corresponding advancement in the future. Let us illustrate by a comparison with the development of other phases of medicine.

The leaning tower of Pisa recalls the unchastened spirit of Galileo[1] leaving the University to become professor of mathematics at the University of Padua in 1592. That which probably represents the first alcohol thermometer was the result of his initial efforts in his new position. Although evidence is scarce, it suggests that nearly two hundred years elapsed before the recording of body temperature was made possible through the development of the mercurial thermometer by Fahrenheit[2,3] about 1714. The Vienna school of medicine began to flourish, under the influence of van Swieten[4], about 1750. It is recorded that he first placed the clinical thermometer in the mouth of medicine amidst criticism which was softened only by the favor of Maria Theresa and Joseph II. Fever continued to be regarded as a disease until Lord Kelvin[5,6] established the "absolute scale of temperature" in 1848 and Wunderlich[7,8] founded clinical thermometry in 1868. More than two hundred and fifty years were required for the accepted application of physical laws to the measurement of body temperature. The value of this procedure is now so generally accepted that every layman anticipates this common practice to be employed by his family physician.

Since 1903, and later in 1906, when Einthoven[9,10] first revealed the possibilities in Leyden, the work of Mackenzie[11,12] and others has been enlarged upon by the use of graphic records for the study of cardiac function. The electrocardiograph has become a part of the equipment essential for the best treatment of heart disease.

There are many other examples, but these must serve to emphasize the fact that measurement is essential for the interpretation of normal and abnormal phenomena of the human body. Empiricism, fostered by trial and error, must continue to govern the therapy of abnormal function until measurement in some form improves the treatment of disabilities affecting the back and lower extremities.

The historical account of the study of gait is, like other subjects in medicine, interesting and lengthy. "Animal spirits" activated the extremities in the time of Aristotle[13,14] (384–322 B.C.). It is said that his grandson Erasistratus[15,16] (310–250 B.C.) first discovered that muscles had the property of contraction.

* From the Department of Surgery, Division of Orthopaedics, Rochester University School of Medicine and Surgery. Funds for this research work have been provided by the Rockefeller Foundation.

† Read before the University of Rochester Medical Society, May 9, 1932.

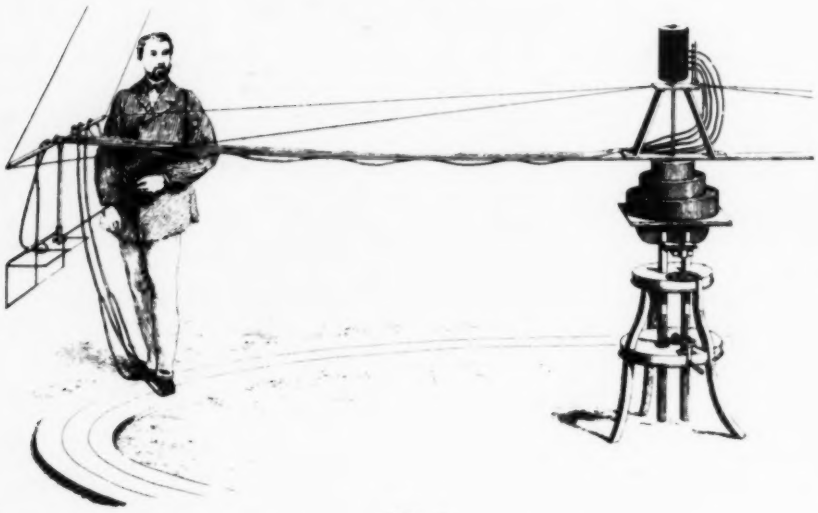

FIG. 1
Carlet's apparatus for recording gait.

The anatomical period was born with Galen [17, 18] (131–210 A.D.) and with it the first intimate knowledge of the origin, insertion, and function of muscles as related thereto. Even with this advantage the history of human locomotion reveals sterility until the inauguration of a new era by Borelli [19, 20] (1608–1679). He is credited with having given first consideration to the (1) motor force, (2) the point of body support, and (3) the resistance to be overcome. As a mathematician trained by Galileo, he introduced the mechanical viewpoint during the period when only observation was applied to the study of gait.

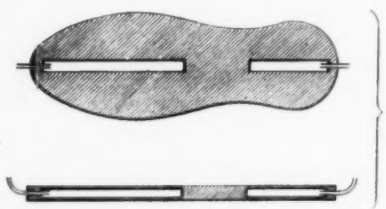

FIG. 2
Sole of Carlet's shoe showing air chambers in mid-line of heel and forefoot.

More than one hundred years later, Paul J. Berthez [21] (1734–1806), of Montpelier, clearly defined the idea that the motive force of the body rests in muscle function. In a memoir published by Chabrier [22] about 1820, the relationship of muscle function of the fixed lower extremity was shown to be inverse to the function of the free extremity. He also included the vertebral muscles in the group essential for normal locomotion.

Twenty-two hundred years elapsed, therefore, during the period when the study of this subject was controlled only by observation of human gait. The experimental period was introduced by the Weber Brothers [23], working in Leipzig, at the beginning of the nineteenth century. Their work represents a detailed study of the structures involved in locomotion while experimental data provided the basis for elaborate mathematical deductions.

Their paper on the physiology of motion and locomotion and the mechanism of the joints was published in 1836. This was the most important work of the period, although many of their major conclusions do not find general acceptance at the present time.

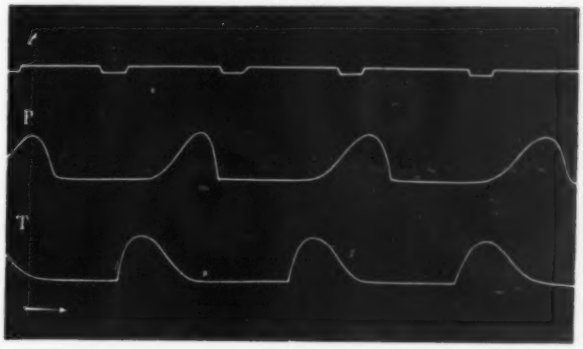

FIG. 3
Carlet's gait curve, P—heel, and T—forefoot, recorded separately.

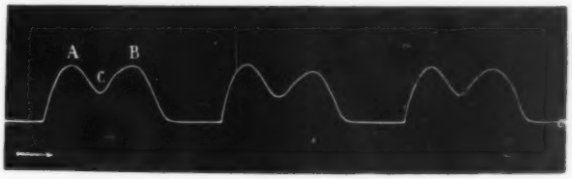

FIG. 4
Carlet's gait curve, A—heel, and B—forefoot, recorded simultaneously.

In fact their theory that the respective legs obeyed the laws of a pendulum was attacked and disproven by G. B. Amand Duchenne[24, 25] (1806–1875), a contemporary working in Paris. The relationship of muscle function to locomotion was settled with finality by demonstrating the impossibility of progression in the presence of paralysis of the flexor muscles of the thigh.

It was not until the last quarter of the nineteenth century that G. Carlet[26], a pupil of Marey's at the College of France in Paris, made the first graphic records of human gait. Shoes with India rubber soles were altered by making an air compression chamber for the heel and forefoot (Fig. 2). Rubber

FIG. 5
Marey's recording mechanism.

FIG. 6
Marey's shoe with one air chamber in mid-metatarsal region of sole.

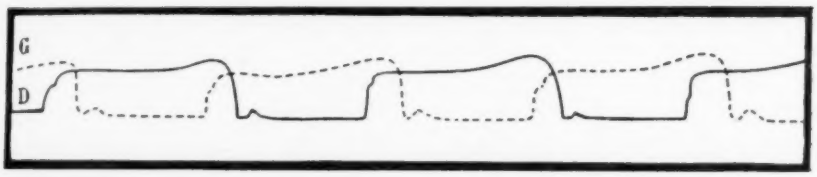

FIG. 7

Marey's gait curve, showing increasing pressure to the point where the pressure is suddenly released by lifting the foot.

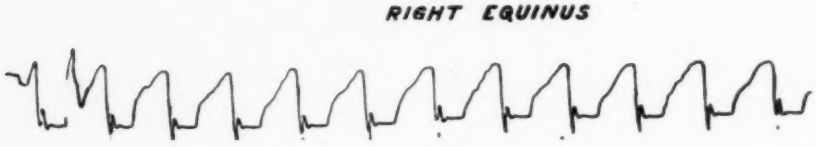

FIG. 8

Author's gait curve of an equinus limp which reveals increasing pressure on forefoot to the point where pressure is suddenly released.

tubes connected these respective chambers with a Marey tambour and a kymograph for recording by means of a smoked drum. Owing to self-evident indications, the latter was mounted on an axis in the center of a circle twenty meters in circumference (Fig. 1). He was of the opinion that the "radius of curvature was sufficiently large so as not to impede, in any way, the walk that one could consider accomplishing in a straight line". This opinion might be subject to question, along with certain other conclusions which he drew. For

FIG. 9

Interior of shoe; air chambers of three cubic centimeters' capacity placed in relation to the tripod of the foot.

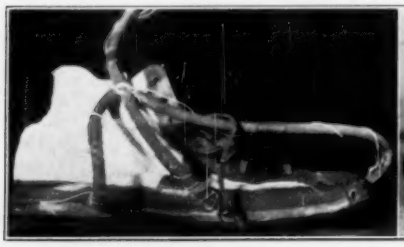

FIG. 10

Exterior of the shoe. The rubber tubes from respective air chambers converge into one by means of a three-way metal connection.

FIG. 11

Sole of shoe. Wires exposed over level of respective air chambers, at level of heel, fifth metatarsal, and first toe, respectively.

the present, it is more fitting that one should express appreciation for his ability and ingenuity, while criticism awaits its proper place. Due to the absence of relationship of the two air chambers to the three weight-bearing points of the foot, his curves of gait (Figs. 3 and 4) did not reveal the function of the tripod of the foot.

In this excellent thesis, one sees the influence of Marey [27] who published his first work on "Terrestrial Locomotion of Bipeds and Quadrupeds" in 1873. While Professor of Physiology at the College of France in Paris, his continued interest in the subject of locomotion is revealed by his bibliography which extended over a period of seventeen years. He constructed a small recording apparatus (Fig. 5) which was carried by the subject and was activated by one air chamber in the mid-metatarsal region of the sole of the shoe (Fig. 6). The character of the curve (Fig. 7) produced by normal gait was therefore comparable to that of an equinus limp (Fig. 8) as recorded by our apparatus.

FIG. 12
First record made on kymograph with smoked paper.

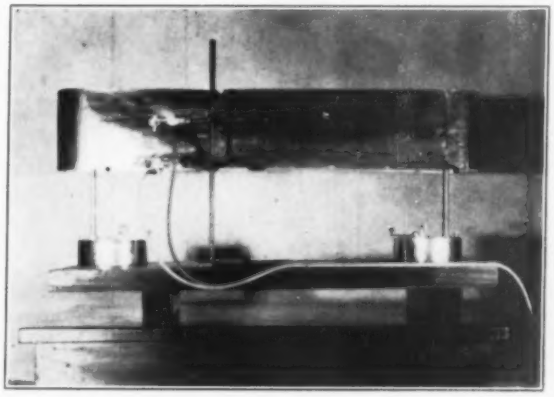

FIG. 13
Two kymographs for making seven-foot record of both right and left foot.

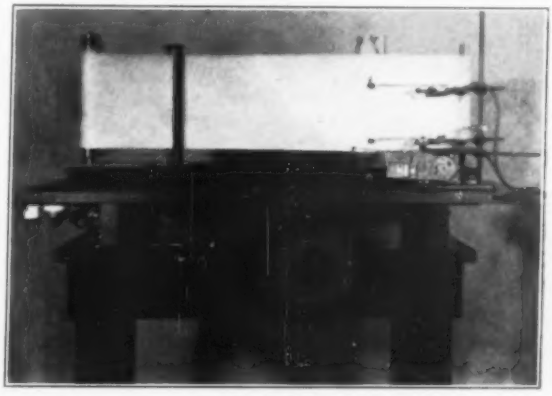

FIG. 14
Continuous recording mechanism showing electric timing mechanism—lower tambour for right foot and upper tambour for left foot.

FIG. 15
Treadmill under construction. Boards bolted to two endless belts.

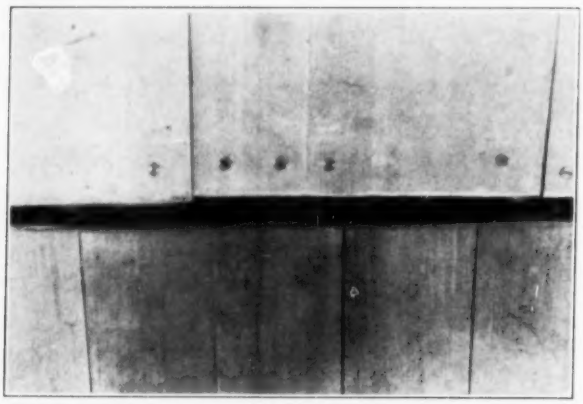

FIG. 16
Treadmill boards covered with aluminum. Brass springs fixed on platform to come in contact with aluminum on the ends of treadmill boards.

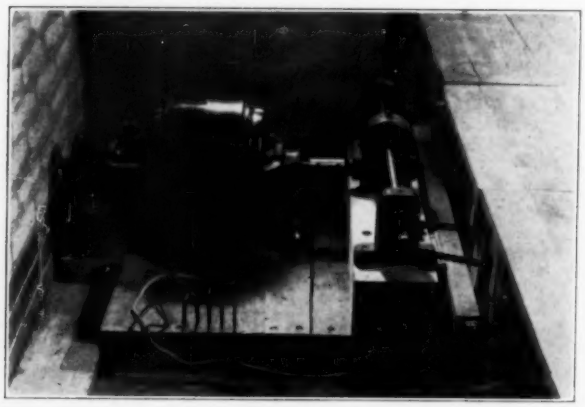

FIG. 17
One-horse-power motor, gear reducer, and chain drive.

The work of Eadweard Muybridge [28] on "Animals in Motion" was begun in California in 1872, later continued and completed at Pennsylvania University in 1885. He employed the electrophotographic method of recording the locomotion of the horse and other animals, including a short study of gait of man. The work of Pettigrew [29], Braune and Fischer [30, 31], Dercum [32], Bloch [33], Richer [34, 35], and others must be passed without description at this time.

Our work, which began in 1926, was expressed in the form of the "basograph" [36] in 1927. This was later abandoned because the principle of the pendulum was shown to be useful within limits which were too narrow to be of practical value. Efforts made in several other directions were equally unsuccessful.

In its present form, the pneumographic method of recording gait requires special shoes. The "normal" foot

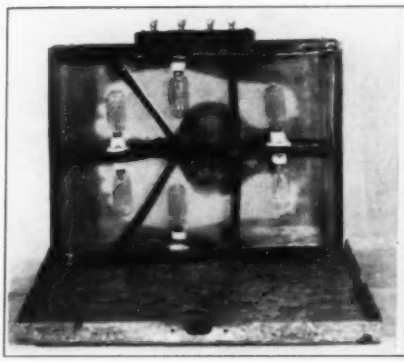

FIG. 18

Back of transillumination box, showing three respective compartments with lights for each foot.

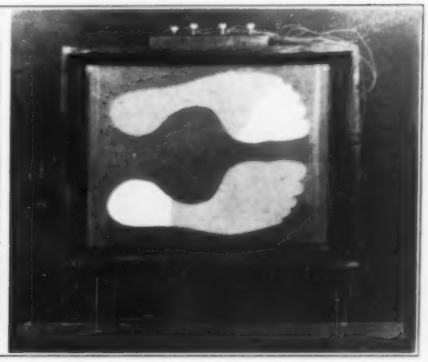

FIG. 19

Front of transillumination box with outline of feet on ground-glass plate. Right heel and left forefoot illuminated.

presents three principal points of pressure in bearing superincumbent weight. We have, therefore, placed the air compression chambers of three cubic centimeters' capacity under the heel, fifth metatarsal head, and the first toe (Fig. 9). A rubber tube of five thirty-seconds of an inch, interior diameter, passes from each of these chambers to the lateral side of the shoe. By means of a three-way metal connection, these are made to converge into one tube of the same size (Fig. 10). This tube from the right shoe is connected with the lower tambour, while a corresponding tube from the left shoe is connected with the upper tambour. The electric timing mechanism records a vertical line on the base line at intervals of five seconds (Fig. 14).

Smoked paper on a kymograph was at first employed to reveal the possibility of getting records by this method (Fig. 12). Two kymographs were then used to provide a record seven feet in length (Fig. 13). The records were consistent from week to week, but this recording mechanism

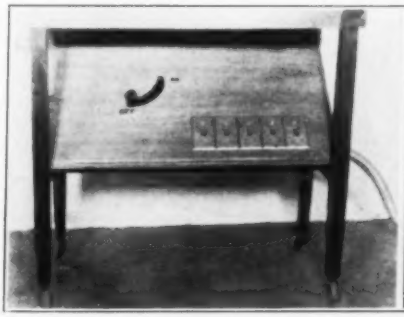

FIG. 20

Front of control board showing lever for rheostat control of one-horse-power motor and five switches for operating all of the equipment.

FIG. 21

Back of the control board showing rheostat, fuse block, and cable which contains the wiring.

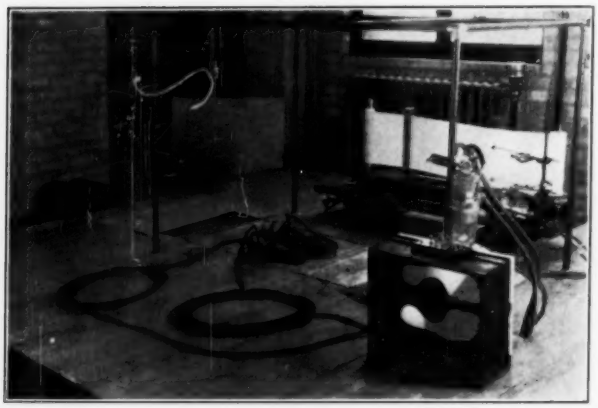

FIG. 22

Arrangement of apparatus, motor, shoes on treadmill, transillumination box, 1300-watt, tungsten, water-cooled lamp, and continuous recording mechanism.

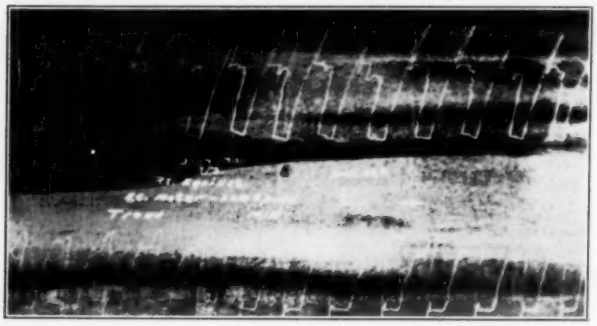

FIG. 23

Gait curves made when subject walked on a concrete floor. Upper curve: left, "normal". Lower curve: right, equinus.

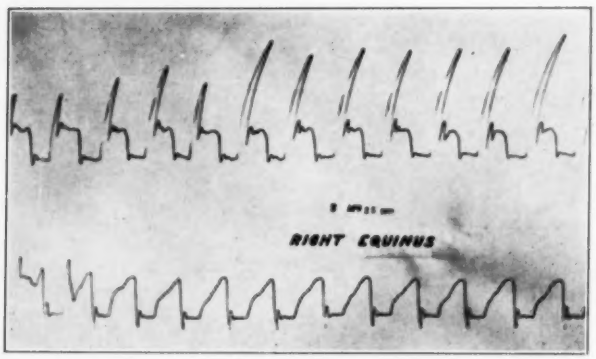

FIG. 24

Gait curves made when same subject walked on the treadmill. Upper curve: left "normal". Lower curve: right, equinus.

was unsatisfactory from every point of view. A continuous recording instrument was constructed to provide ink records by using pens made from acetate film and special capillary tubes (Fig. 14).

Foreseeing the necessity of reducing the interpretation of these graphic records of gait to the medium of physical laws, it was essential to construct a treadmill. A section of the conveyor system from the Eastman Kodak Company was used as a foundation (Fig. 15). Boards were bolted on two endless belts to provide a smooth surface comparable to a floor. The surfaces of these boards were covered with aluminum which was made to overlap the ends on the left side. A six-foot strip of brass, one-eighth of an inch thick and one inch wide, was fixed to the left side of the platform surrounding the treadmill. Brass springs, one inch wide and four inches long, were

made to touch the overlapping edges of the aluminum (Fig. 16).

These springs formed one side of an electrical circuit. The other side was formed by wires in the soles of the respective shoes. These wires were exposed over the levels of the respective air chambers at the heel, fifth metatarsal, and great toe (Fig. 11). Each of these respective wires was led to a light in the corresponding compartment of a transillumination box (Fig. 18) which had the soles of the feet outlined on a plate of ground glass (Fig. 19).

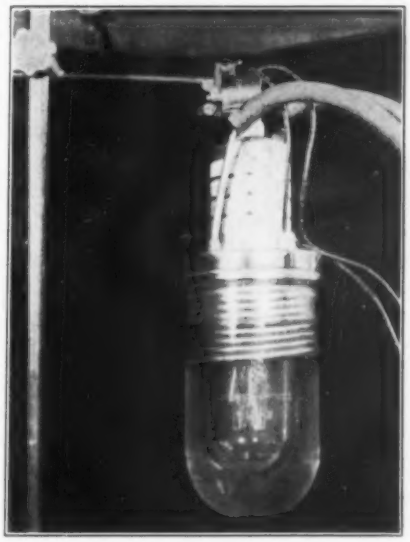

FIG. 25

Thirteen-hundred-watt, water-cooled, tungsten filament lamp.

The treadmill is driven by a one-horse-power, direct-current motor through a gear reducer (135 to 1) with chain drive on sprockets with a ratio of 20 to 36 (Fig. 17). This gives the treadmill a maximum rate of travel of four miles per hour. Slower rates of speed are possible through the use of the rheostat on the control board (Fig. 20).

This control board (Figs. 20 and 21) also carries five switches which operate the spot lights, the transillumination box, the water-cooled, thirteen-hundred-watt, tungsten lamp (Fig. 25) and the continuous recording mechanism, all of which are shown in Figure 22.

The records produced have been made on both a fixed surface—such as a concrete floor—and on the treadmill. These records are very similar in their characteristics. In support of these and other statements made pertaining to the pneumographic method of recording human gait, the evidence was based on records sufficient to form one continuous strip, one hundred and twenty feet in length. They were made on various dates between January 6 and May 5, 1932 inclusive. The present indications are, therefore, that the treadmill may be used, at least in some instances, without essentially altering the gait curves (Figs. 23 and 24).

The analysis of these records has been made possible through the use of moving pictures. A sixteen-millimeter camera is focused on the subject, the treadmill, the recording mechanism, and the transillumination box as revealed in Figure 22. While the subject walks on the treadmill at the rate of four miles an hour, the curves are being continuously recorded and the transillumination box reveals the respective points of pressure; pictures have been made at the rate of sixteen, thirty-two, and sixty-four exposures per second. Subsequent projection provides for study, interpretation, and analysis in slow motion.

Four hundred feet of moving pictures showing all of this apparatus,

together with the method of recording "normal" gait and imitated limps, have been made.

CONCLUSION

Our problem is the analysis of gait. The method of approach is as follows:

1. The development of the physical mechanism essential for making graphic records of normal and abnormal gait. In this paper we have presented evidence which suggests that the pneumographic method may serve this purpose.
2. The classification and analysis of "normal" curves on a basis of given age, weight, and height of subjects is the next phase of our work.
3. The analysis of gait curves which result from abnormalities of known etiology in individuals of the same age, weight, and height group must then follow.
4. Our goal is the determination of the influence of treatment of known pathology as revealed by graphic records of individual gait.

The Advantages to be Gained by This Research Program

Through the development of a method for recording gait and the subsequent analysis of the curves produced, abnormalities in function of the lower extremities may be brought under the influence and control of comprehensible physical laws. Progress, under treatment, should then be determined by the same method of measurement.

Facts, instead of opinions, therefore, may in the future be used to define the prevailing limitations in function. Only through the use of analyzed curves, indicating the presence or absence of improvement, may the repeated mistakes of empiricism be eliminated from the treatment of deformities. The correction of deforming limps constitutes a large part of orthopaedic surgery. From year to year, this work has continued to be directed by opinion. This branch of surgery may be brought under the influence of physical laws only by continued encouragement of systematic efforts.

NOTE.—In the paper as read, the following acknowledgment appeared as the Introduction.—EDITOR.

It is essential that you should be apprized of those to whom I am indebted for the privilege of presenting this work on gait. Dr. George H. Whipple, Dr. John J. Morton, and Dr. Wallace O. Fenn have made it possible. Over a period of several years, advice and assistance have been sought from many sources. Dr. Fenn, Dr. Stafford L. Warren, Mr. Francis W. Bishop, and Dr. John R. Murlin's Department of Vital Economics have all been most helpful. Dr. Milton Chapman, Dr. William A. Sawyer, Mr. Gustave F. Aldinger, Mr. Harris Tuttle, and Mr. Fordham Tuttle of the Eastman Kodak Company have given valuable assistance and cooperation. Mr. E. H. Branson and Mr. Walter H. Hoppe of the General Railway Signal Company were also generous with time and assistance. Mr. F. W. James of the Bausch and Lomb Optical Company located the motor and gear reducer for the continuous recording mechanism, and the one-horse-power motor which now drives the treadmill. Without his immediate help at the time, this work would have been materially delayed. To Mr. Jack Schabert, of the Taylor Instrument Company, must be given credit for having provided the capillary tubing upon

which we were dependent for successfully recording with ink. The success of this method of recording is shared with the Telautograph Company of New York. From there we received the particular ink essential for our purpose. Directly and indirectly we are indebted to Mr. Harry Gordon of the Rochester Telephone Company, for parts made useful from old switch boards which had been given to Dr. Warren. Mr. Edward A. Knight, Mr. Charles Alberts, Mr. W. H. Woodworth, and Mr. C. Beach have willingly and freely placed their respective shops at our disposal. An expression of appreciation must be made for the loan of a thirteen-hundred-watt, tungsten, water-cooled lamp by the General Electric Company, through the kindness of Mr. John G. T. Gilmour.

To utilize the fullest advantage of this combination of resources and successfully build the present equipment essential for the study of gait, required the interest of a person of ability who was willing to work. Mr. Arthur L. Heath is responsible for the construction of the present experimental apparatus. He has, for the past three months, been ably assisted by Mr. Charles Brown. With all of this cooperation, I appear before you as the spokesman for my colleagues.

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THE RÔLE OF SYNOVECTOMY IN CHRONIC INFECTIOUS (PROLIFERATIVE) ARTHRITIS

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Until the time shall arrive when, given a patient with the early symptoms of arthritis, the course of that case may be confidently predicted and crippling deformities and disabilities forestalled by treatment, there will always be individuals for whom Nature's efforts must needs be assisted by surgery. If experience and observation teach us anything, it is that the local manifestations of toxic invasion of a joint are indicative of the same cellular responses that one expects to find in any tissue subjected to the inroads of bacteria and their toxins, modified chiefly by the nature of the tissues involved. Furthermore, it is common knowledge that infections vary in virulence, and individuals are possessed of different degrees of resistance to bacterial infection. This is quite as true of those infections giving rise to arthritic changes as of any other infective lesions. It is a fairly well established conclusion that there is machinery in the human body that is thrown into action just so soon as systemic bacterial invasion takes place, which elaborates biochemical substances tending to render the invading toxins inoccuous. In addition to this systemic reaction there will be local defensive measures taken which are designed to prevent extension of infected areas by enveloping them within a cordon of connective tissue. The more chronic the infection, the more probable is it that synovial erosions will not be the dominant feature of the damage inflicted upon the interior of the joint. Proliferation of the normal synovial villi, if unaccompanied by loss of their synovial coverings, does not hold the possibility of so much disablement of the affected joints as is the case in more acute infections where denudation of synovia and toxic erosion of cartilage pave the way to deformity and loss of motion. Proliferative changes in the villi at the line where the synovia is reflected from the cartilaginous margins cause them to creep in over the articular cartilage in the form of a pannus which sends down loops of newly formed blood vessels to penetrate the articular surface and attach themselves, as do the "runners" of certain plants that propagate in that manner, sinking their rootlets into the soil, remotely from the mother plant. In all chronic infections of joints, villous changes are an early and a common, probably a constant, sign. Invasion of the joint is through the arterial stems supplying the individual villi and it is through stomata in the walls of these vessels that organisms or their toxins escape, setting up, at once, a round-celled infiltration. Simultaneously there is inaugurated in the connective tissues a reparative reaction. In the course of time, and in patients whose resistance is good, the villous hypertrophy subsides by the metaplasic route. I have had occasion to observe the nature of this change in a number of operative cases. Apparently the villi undergo a fatty degener-

ation, beginning at the tip and extending back to the base. I have seen individual villi with single, large, opalescent fat droplets on the tips of the stalks and I have observed in advanced cases these individual droplets coalesce into a pannus of solid, homogeneous fat, unencapsulated, and easy to strip off the synovial wall, leaving a smooth, soft surface and a synovial membrane apparently normal in all respects except perhaps a trifle thickened. The pathology of all types of the proliferative (toxic) variety of arthritis, so far as the joints are concerned, lies in the villous folds of the synovial membrane, at least in the beginning, and the type of villus to be met is more dependent upon the chronicity of the underlying infection than upon the particular bacteriological strain causing it. The acute gonorrhoeal invasions of joints develop their joint pathology so rapidly that villous proliferations have no time to form and one finds a thick, oedematous synovial membrane. The layers of lining cells of this synovial membrane have been rapidly denuded and the deeper-seated connective tissues quickly multiply so that many and firm adhesions are formed within a short time after the joint becomes involved. Almost no villous hypertrophy will be observed in these acute cases.

Another common type of infection occurs without bacterial specificity and is characterized by very numerous, dark, purplish-red villi. They are short and stubby with their synovial coverings intact. Some excess of fluid may be found in the joint and perhaps a few fibrinous clots floating about or adherent to the villi. When the capsule is incised in performing an arthrotomy, the edges of the wound evert and these villi are turned out into the wound in such numbers that the interior of the joint cannot be inspected until the incision has been greatly extended and its edges retracted. This type is subacute in its intensity as compared to the fulminating gonorrhoeal variety to which reference has just been made. These patients may show multiple joint involvements and there has always been evidence of inflammatory reactions in the joints and often constitutionally as well. A second and more chronic variety of villous hypertrophy, accompanied by less acute clinical signs, shows more massive villi, often branched, in which the synovia is intact. It is in this type that the majority of the fatty degenerative changes have been observed.

Apart from damage inflicted upon the joint by the possible invasion of the articular cartilage by the pannus and its consequent impairment of function, there is a tendency to distend the capsule, rendering the joint unstable and less capable of normal and comfortable action. In such cases it is desirable to explore such articulations with a view to removing any products of previous inflammations and such villous remains as threaten to erode cartilage and provoke a situation that will increase liability to ankylosis and deformity. Synovectomy offers the best opportunity for preventing certain of these disabilities in carefully selected cases, and, if arthrotomy for this purpose is decided upon, it should be through the median-patellar incision which gives by far the best opportunity to inspect the joint and remove whatever requires removal. Con-

valescence from this procedure is not longer than from other approaches—often not so long—as early active measures to restore flexion are not contra-indicated.

A brief summary of the following four cases will indicate what is reasonable to expect in patients of the types described.

CASE 1. Miss E. H., twenty-three years old, single, is an intelligent girl, a secretary by occupation. There was nothing of significance in her history prior to the onset of her present symptoms which were first related to me in November, 1930. When she was seventeen years of age she had an acute attack of pain and swelling in her left elbow. She was treated for acute articular rheumatism and the symptoms subsided in a few weeks, only to be followed by similar signs in the right wrist and certain of the phalangeal joints of the right hand. The trouble here was not so acute or disabling as had been the case with the elbow, but symptoms persisted in both localities for two years before the right knee began to swell. The knee has continued to trouble her, gradually becoming more painful and recently beginning to flex. About fourteen months after the right knee started to swell, the left knee began to behave in the same manner and when I first saw her she was so disabled that she was brought to my office with great difficulty, requiring the assistance of two persons to carry her. She could not get out of a chair alone and could only walk with a person on either side, supporting most of her weight, and at that very slowly and painfully. She was twenty pounds under her normal weight. She was anaemic (hemoglobin sixty per cent.) and was suffering a great deal of pain on motion of the affected joints. The left elbow was flexed thirty-five to forty degrees, was much swollen, the surface temperature was increased, and there was a coarse crepitus to be felt when the joint was flexed the few degrees in which this motion was possible. The swelling was capsular. The right wrist had little motion, was swollen and warm to touch, as were also two of the second phalangeal joints on the right hand. Both knees were much enlarged, particularly the left; both were permanently flexed about twenty to twenty-five degrees. There was marked capsular thickening, increase in surface temperature, and motion in flexion to slightly beyond a right angle was painful and guarded by spasm. During the summer preceding the November in which I saw her, she had been treated in casts at a Boston hospital for five weeks and during the rest of the time she had been having sun baths. Fearing an extension of a pannus of synovial villi over to the articular cartilage, some suggestion of which was evident in an x-ray which was taken at that time, an arthrotomy of the right knee was advised and performed the latter part of November, 1930. The joint was opened through a long lateral (internal) incision. The capsule was found much thickened and, as soon as it was incised, there was an escape of a slight amount of clear synovial fluid, without flocculi, and an immediate extrusion of small, dark-purplish villi which were encroaching upon the articular cartilage. There were no demonstrable adhesions and no actual erosion of cartilage. These villi were quite freely removed by scissors dissection from the quadriceps pouch and from the space on the inner side of the joint where the synovial membrane was reflected back from the cartilage, as well as at the origin of the alar ligaments. The joint was washed out with a considerable quantity of hot saline and the capsule and skin closed without drainage. No cast nor any fixative splint was applied. She recovered well from the operation and by the autumn of 1931 had improved to such an extent that she could flex the operated leg to well beyond a right angle, and could practically fully extend it. The swelling never recurred in the knee and it was relatively painless. The left knee showed no change. The elbow had improved, though nothing had been done for it locally except to keep it bandaged with an ace bandage and to prohibit its use. In September, 1931, she had a dozen intravenous injections of oxybenzoate by her family physician, in the hope that her other joints would be benefited. During the fall and early winter she was able to get about more, the swellings disappeared, her general condition improved, and, in February, 1932, she came to the office alone, walking without pain or limp and showing no capsular

thickening in either of her knee joints, a nearly normal range of motion, and an elbow that could be almost fully extended, was painless, and manifested no acute symptoms. The phalangeal joints were slightly more prominent than their fellows and the wrist was still somewhat restricted in motion but caused her no trouble. Her anaemia had disappeared and her weight was only a couple of pounds under what had been her best weight. She was ready to resume her secretarial work. The following is a report from the pathologist to whom the material removed from the knee joint was submitted:

"Specimen consists of three pieces of tissue the largest of which measures two centimeters in length and one centimeter in width and eight millimeters in thickness. The other pieces of tissue are somewhat smaller. On section the tissue is pinkish red in color and firm in consistency. The pannus submitted has essentially the same appearance as the other pieces of tissue. Due to its size it is fixed without further sectioning. Sections microscopically through the tissue submitted show it to be composed for the most part of fibrous tissue containing a few blood vessels, showing marked round-cell infiltration characteristic of a chronic inflammatory process. The pannus seen grossly contains numerous blood vessels and also shows moderate round-cell infiltration. There is no evidence of malignancy or tuberculosis in the tissue submitted."

Case 2. Mrs. S., forty-four years old, was first seen October 22, 1930. Patient had had no trouble with her joints until eight years before, when her last baby was born. Three weeks after that she had pneumonia and was in bed five months. When she was a school girl, for six or eight winters, she used to have bad attacks of tonsillitis. As a young woman of twenty she had acute articular rheumatism, but made a complete recovery. She had her tonsils out and her teeth were negative to x-ray. After the pneumonia she was all right for a year, when her right wrist and the second joint of the right middle finger began to swell and pain her, and a little later the right and then the left knee became involved. These were painful, red, and tender, as well as swollen. After that the joints slowly but steadily grew worse and a year before the patient came for examination these joints had begun to contract, and this tendency had increased. She was getting about the house with a good deal of difficulty, but still doing most of her work. If she was not on her feet she suffered no discomfort and there was no increase in the swelling. No new joints had been attacked. The wrist was not swollen when examined and there was no pain nor restriction of motion. The middle finger was still enlarged at the second joint. Both knees were swollen capsularly with some excess of fluid but no heat. Motion was possible to full extension and nearly full flexion. X-rays taken one year before were said to have been negative. Hips were normal in motion, though she said that in sitting she had some discomfort in them. General health was excellent. The diagnosis was an apparently quiescent villous arthritis of both knees with little active arthritis. Synovectomy was advised. At the time of the operation, which was performed in October, 1930, the two knees presented much the same condition. The right one was operated upon two weeks before the left; in each a lateral incision was made over the inner aspect of the joint. The quadriceps pouch was freely incised from above down, the incision being carried well below the line of the joint. There was a moderate excess of fluid in both knees with a good many flocculi floating in the fluid and a few adherent to the villi. The villi were quite good size, were dark-purplish in color, and a few were arborescent with an occasional suggestion of beginning fatty degeneration at their tips. There were no firm adhesions anywhere. In the quadriceps pouch, finger dissection met with some opposition which was easily overcome. For a half inch in from the reflection of the synovia on the inner condyle the cartilages were covered by a pinkish-colored, non-villous pannus which, when stripped off, showed a roughened, striated cartilage beneath. A large quantity of hypertrophied villous material was removed by scissors dissection. The joint was thoroughly washed with hot saline and the capsule, which was fully three-eighths of an inch thick, was closed with interrupted chromic catgut sutures. The skin was closed without drainage. Passive motion was begun on the knee first operated upon at the end of a week, but this was interrupted for a week after the second knee was done. The woman was in the hospital one month and began to get about on crutches in five weeks. She was last seen in November, 1931, when she was getting about very comfortably, unsup-

ported, could go over the stairs—which she had not been able to do for nearly a year before she was operated upon—had normal flexion in both knees, but could not extend the right quite as fully as the left, and there was no excess of fluid in either joint. There did not appear to be any capsular thickening. She reports that she is steadily increasing the range of her painless activities. Pathological examination was essentially the same as reported in Case 1.

Case 3. Mr. T. M., forty-four years old, is a cook. He has to be on his feet for nine hours a day for the greater part of the time. He has a congenital dislocation of the right hip which does not trouble him much. About ten years before, without any known cause, he had begun to have swelling in the left knee and shortly after in the right, and ever since he had had alternate aggravation and recession of the swelling in both knees, on a four-day "cycle". When the left was at its maximum, the right was at its minimum. When the swelling was down, there was not much discomfort or disability. When at its height it was very uncomfortable and disabling. There were no other symptoms, local or constitutional. Physical examination showed a well developed and nourished man with congenital dislocation of the right hip. He walked with limp, using two canes. Left knee was quite swollen, right one less so, apparently not due to hydrops wholly, but probably caused chiefly by villous thickening,—a typical case of intermittent hydrops. Heat was the only agent that offered him any relief. He was given Fowler's solution and quinin for a month. Synovectomy was then to be tried if he was not relieved. On March 4, 1931, the right knee was operated upon, when the swelling was in the recessive stage. The joint was full of small purplish villi among which in places there was considerable fibrinous clot, adherent to villi and free, with no great excess of synovial fluid. A lateral, external incision was used. The villi were freely dissected with scissors. Some pannus formation was found over the internal condyle. There was a considerable accumulation of fluid in the joint following the operation, which subsided in two weeks. Since then there has been no indication of the former periodic swelling. The knee is still somewhat thickened on either side of the femoral condyles but the quadriceps pouch is free from swelling. He is able to walk much more comfortably and to do his work with far less difficulty. The periodicity in the swelling of the left knee has also ceased, but the joint is about two inches larger than the operated knee. The patient is awaiting a favorable opportunity to have that joint treated in the same way. Motions in the right knee are practically normal.

Case 4. Mr. L., fifty-three years of age, is a merchant who had been suffering for over six years with pain, swelling, and disability steadily increasing in several joints. The first to become involved were the right elbow, both wrists, two or three of the metacarpophalangeal joints of the right hand, and, about two and a half years later, the right hip and right knee. He had had various sorts of treatment for the smaller joints, mostly medical and dietetic in character. They progressed with varying success and at the time he was first seen by the author, on account of the trouble with his knee and his hip, these earlier affected joints were fairly quiescent, with some loss of motion in the wrist and about fifteen degrees of permanent flexion at the right elbow with a little swelling on either side of the olecranon process. The metacarpophalangeal joints appeared to be somewhat enlarged, chiefly due to the interosseous atrophy. His general condition seemed to be very good. His tonsils were not enlarged or reddened, the teeth were in good condition, but he was having some intestinal disturbances in the form of gas and a certain amount of discomfort after eating, referred to the epigastrium. He was hospitalized for a short time to see if it were possible to discover any focal infection. Unless it were gastro-intestinal, there did not appear to be any such focus. There was a slight amount of secondary anaemia. Local bandaging to hip and knee, high oil enemata, and general hygienic treatment were followed out for a year with but little betterment. There were no acute signs in the knee. X-rays were negative. Fear of the inroads of a villous pannus led me to urge a synovectomy which was performed in 1931. In this case a median patellar incision was employed, which gave an excellent view of the joint. The capsule was not very greatly thickened. The quadriceps pouch was occupied by a

yellowish, homogeneous mass of fat, unencapsulated, which could be easily dissected away from the basement membrane, leaving a smooth surface, a trifle thicker than the normal synovia, without rugae, and of a normal color. Over either condyle and at the reflection of the synovial membrane there were still some villous enlargements, many of which were showing terminal fat drops. Convalescence was uneventful; passive motion was started in a month, and walking with weight-bearing was permitted at the same time. Full motion in flexion and extension was allowed in seven weeks and walking with full weight-bearing soon followed. All swelling had subsided and walking, so far as the knee was concerned, was a comfortable proceeding. Because the right hip still caused a little disablement in locomotion, and the wrists and elbows (though nearly symptomless except for such restriction in motion as the arthritis had already caused) still appeared to harbor a little activity of the infection, it was thought advisable to give the man a course of intravenous oxybenzoate injections. This was accordingly undertaken by Dr. Albert G. Young with a very satisfactory outcome.

These four cases differ considerably in type, more perhaps in the observation of the individuals than one would glean from merely reading the above descriptions. The girl described in Case 1 was a sick person. She had quite a severe infection or was lacking in resistive power. Constitutionally she manifested fully as much reaction to the invasion, whatever it may have been, as she did locally in the joints. Case 2 was that of a woman whose constitutional reaction was slight. She had had acute articular rheumatism and she had been very sick with pneumonia, following which a polyarthritis developed which gave rise to rather acute symptoms in certain of the articulations. Gradually these features subsided, leaving her seriously handicapped in her ability to get about, but unaffected in respect to general health and with no progressive tendencies in other joints. Case 3 was that of a man who for several years had suffered from intermittent hydrops in both knees. No other joints had ever been affected; no focal infections were determinable. Apparently a rhythmic lack of vasomotor control over the circulation in the villi of his knees was the cause of his symptoms. He was the picture of health in all respects and able to do his work—which involved constant standing—under a good deal of handicap but without great discomfort except for the short interval when each knee was at its maximum of distention. The man described as Case 4 possibly had a gastro-intestinal origin for his low-grade polyarthritis, which was tending to subside because of his high resistance to the infection and the excellent general care he had taken of himself. One joint only was causing him much inconvenience and in this the villous hypertrophy had undergone a complete metaplasic transformation to fat.

In all these cases, except possibly the first, the value of synovectomy to the patient was the removal of that which had accumulated within the articulations as a result of cellular reaction to toxic invasion and, though at the time inoccuous, was putting the joints at a mechanical disadvantage, too long a continuance of which might have resulted in permanent disability. That I conceive to be the *raison d'être* of synovectomy and only such cases as present that condition and probable outcome should be subjected to it.

FRACTURE OF THE FEMUR IN CHILDREN*

BY C. F. EIKENBARY, M.D., F.A.C.S., AND JOHN F. LECOCQ, M.D., SEATTLE, WASHINGTON

Fracture of the femur, in either a child or an adult, is decidedly a major problem. The treatment of such a condition requires considerably more than the ordinary amount of skill. To treat it lightly or carelessly means a poor result, and a poor result means that a handicapped individual has been created. When we stop to think that the entire future of the individual depends upon the care, the skill, and the thought that we give to such a patient, it should give us pause for considerable reflection before we decide upon any one course of treatment; and if there are any misgivings as to just what should be done, skilled consultation should be sought. Many a crippled individual walks the streets today merely because his fractured femur was considered too lightly. Also, there are probably many more disabled individuals walking the streets because, in our anxiety to get a beautiful radiographic result, we have resorted to open operation.

There are cases that may require open reduction. They are very few indeed. We feel that we are consistent in saying that at least ninety per cent. of the cases operated upon would have been infinitely better if operation had been avoided.

Just what should be the aim in the treatment of a fracture of the femur? There can be but one answer,—the restoration of normal function. Normal function *should not be estimated by the radiographic appearance.* Just what are the requisites for the restoration of normal function? There are three: (1) union; (2) normal alignment; (3) normal length. There are no other requisites. The surgeon who thinks in terms of radiographic appearance will, perhaps, wonder why we have not included normal apposition. Normal apposition, while it is desirable, has very little bearing on the result so far as function is concerned. It has been demonstrated in literally thousands of cases that union will occur, certainly in children, even though the apposition is very slight. In fact, it will occur almost certainly, even if there is apparently little or no end-to-end apposition. Several inches of overlapping generally does not prevent union, though naturally such a condition should not be tolerated, owing to its marked disturbance of function. Normal function should be our aim, first, last, and always, in the treatment of any fracture.

Open operation generally may be productive of normal apposition and normal alignment. This being true, what are the objections to open operation? First, union is invariably delayed. This statement has been proven so many times that argument along that line should not be neces-

* Presented at the Annual Meeting of the American Orthopaedic Association, Toronto, June 18, 1932.

sary at this time. Delayed union means longer fixation, longer period of hospitalization, delay in the restoration of the movements of the knee and greater atrophy of muscles. Second, the danger of infection. Infection generally means osteomyelitis, resulting in permanent fibrosis of muscle, and, in the end, a knee with marked limitation of movement. Also, shortening is very likely to occur, producing an unavoidable interference with the normal function,—in other words, a permanent crippling condition.

We realize full well that there are many surgeons who can operate on a femur, place the fragments in normal apposition, and obtain a perfectly functioning knee. We realize just as fully that there are many surgeons who cannot. The latter group comprise the surgeons who operate only occasionally, who probably would not be called upon to operate upon more than two or three cases a year. If one case in twenty-five becomes infected (this probably is a low average), then it would seem to us that the operation becomes prohibitive. If our percentage of infections in any line of clean surgery exceeds two per cent., we certainly have no right to risk the opening of a fractured femur, except under the most unusual circumstances. Mechanically, the procedure is ideal. Practically, it is one of the most dangerous procedures in the whole domain of surgery, dangerous to the future welfare of the patient. The future welfare of the patient is paramount to the conscientious surgeon.

Fractures of the upper third, non-intertrochanteric, may require open operation. If so, the operation should be done under conditions as ideal as humanly possible. Under no other conditions should the operation be attempted. As upper-third fractures may require open operation, we are not making any attempt to discuss this fracture at this time. We are concerning ourselves almost entirely with fractures of the lower and middle thirds.

About two years ago, in the Children's Orthopaedic Hospital, we began using the so called Russell's balanced traction. Our results have been so uniformly good that the procedure is now a routine. Of approximately forty cases treated, one hundred per cent. have perfect functional results. We realize that no treatment is going to give one hundred per cent. of perfect results; but any treatment of fracture of the femur which can give such a percentage of perfect functional results in forty cases is worthy of earnest consideration. Not one patient has had the slightest impairment of function. The average period of disability in these cases is about nine weeks—that is, at the end of that period, the patient is walking normally.

In many of the cases treated at the Children's Orthopaedic Hospital, we were not able to secure perfect apposition. In some of the cases the apposition was not more than a half or a third of the bony diameter; but in all cases we readily secured full length and perfect alignment—two absolutely essential requisites. We have ceased to have any concern whatever over the question of perfect apposition.

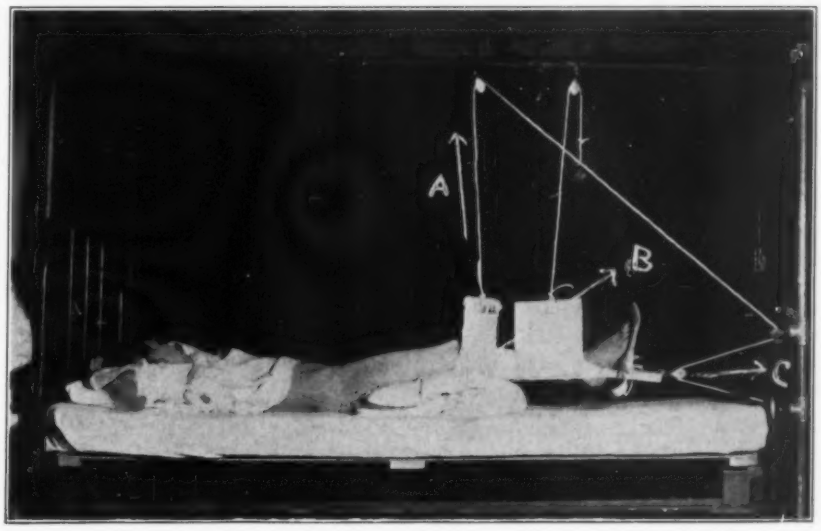

FIG. 1

Note the slight flexion of the hip and knee. The component of traction *A* plus traction *C* is traction *B* in the long axis of the shaft of the femur.

There have been several descriptions of the Russell balanced traction, but it may serve a useful purpose to give again a brief description.

The child is placed either on a firm bed or a frame, the frame being entirely unnecessary; the frame may facilitate the handling of the patient, but it is not essential. Hospitalization is desirable, but is by no means a necessity. Under intelligent supervision, the treatment can be carried out quite well in the home. The hip is placed in a position of about twenty-five or thirty degrees of flexion, and the knee in about the same angle. Abduction or adduction may be secured as desired, merely by shifting the frame to which the pulleys and ropes are attached. English moleskin is used for traction, but the ordinary zinc-oxid adhesive may be used. The moleskin adhesive is much less irritating. The adhesive strips are carried from the malleoli to a point just *below* the knee. It is quite important that the adhesive should not extend above the knee. The two adhesive strips are fastened to a foot piece by means of buckles. In the bottom of the foot piece a pulley is secured. A sling approximately five inches wide is placed under the knee; the upper margins of the sling are tunneled for the two tongue blades, the blades preventing wrinkling. From the center of the upper margins of the sling and going around the tongue blades, a rope is passed over a pulley attached to the frame that goes over the bed, as shown in the illustration. This rope should go almost directly upward from the tibial tubercle. The rope is continued over the pulley in the top of the frame, is carried downward to the upright of the frame at a point almost opposite the foot, where it passes through another pulley, thence over the pulley in the foot piece, and back to

another pulley also fastened to the upright. The weight is then attached. Usually five pounds are sufficient, but occasionally seven or ten may be necessary. The thigh is supported on a pillow, and the leg may be supported either on a pillow or by means of a sling. It is well to slightly elevate the foot of the bed. The patient is now in the position of balanced traction, the thigh and knee being in a position of physiological rest. The component of the pull on the legs and the vertical pull at the knee is in a line that bisects the two pulls, which is practically in the long axis of the shaft of the femur. The traction comes directly at the knee joint, and therefore is almost the same as skeletal traction. It may exert not quite as much of a pull as skeletal traction, but practical experience has repeatedly demonstrated that, with from five to ten pounds weight, the lower fragment can be pulled down within from two to forty-eight hours to a point where there may be an actual lengthening. The traction is maintained from three to four weeks. If for economic reasons it becomes necessary to send the child home from the hospital, a plaster support may be applied at the end of three weeks. If possible, a plaster support should be dispensed with. The wearing of a plaster support delays the complete return to normal function, the delay being practically the only objection.

The procedure herein outlined is not superior to the use of piano-wire traction after the method of Kirschner. Practically, however, it is fully as efficient because of the complete relaxation, owing to the position of physiological rest. We have found it far superior to vertical traction with full extension of knee; it is also preferable to the ordinary Buck's extension with the knee extended in a line with the body. Traction on the mid-thigh, at the site of fracture, is a most inefficient method. The pull comes on the bellies of the muscles that have their origins from the pelvis. There certainly is very little of the pull that is ultimately transferred to the distal fragment. Forty pounds of pull will accomplish infinitely less when the pull comes at the mid-thigh than can be accomplished by five pounds as used in the Russell balanced traction.

Finally, the comfort of the patient should be emphasized. The patients treated by the method we have outlined are thoroughly comfortable; they can be placed on the bed-pan without fear of doing any damage, and pain is almost nil.

SUMMARY

1. Forty-one consecutive cases have been treated by Russell balanced traction.
2. Only one of these was a fracture of the upper third.
3. The oldest patient in the group was eighteen years of age.
4. The youngest patient was nineteen months old.
5. Not one patient has the slightest disability.
6. In no case was there any shortening or malalignment.
7. The average period of disability was nine weeks.

ALCOHOLIZATION OF PERIPHERAL MOTOR NERVES OF THE LEGS IN SPASTIC PARALYSIS OF CHILDHOOD *†

BY RALPH R. FITCH, M.D., ROCHESTER, NEW YORK

In a recent article on "Cerebral Spastic Paralysis in Children", Dr. Edwin W. Ryerson of Chicago has presented this subject in an excellent manner.[1] Since there is already too much repetition in medical literature, and as I concur in a very large degree with the statements of Dr. Ryerson, I shall not attempt to consider the matter as a whole, but shall limit myself to the question of therapy.

Most of the physical disability which is caused by spastic paralysis is due to a lack of balance of power between spastic and non-spastic groups of muscles. Treatment of this condition must therefore have for its main object the equalization of power between these opposing groups. The fundamental to be desired in such treatment is to build up the power of the weaker group or groups of muscles. This can be accomplished only by muscle training. To make such training practical, the spastic muscles must be weakened or paralyzed, at least temporarily. How shall this be accomplished?

Years ago Foerster recommended resection of the posterior nerve roots. The magnitude and uncertainties of this procedure have caused it in large measure to be abandoned. Sympathectomies of Hunter and Royle have proved, in the hands of most surgeons, to be of use in a very limited number of cases. Stoffel's operation, cutting the peripheral nerve supply to spastic muscles, has proved of much value.

When a motor nerve is divided, the result is permanent paralysis as it is not practical to suture such a nerve. If one divides too little of the nerve supply our aim is not attained. On the other hand, if too much is divided, there will result a loss of muscle balance which may prove to be worse than the condition which we are trying to improve.

With these facts in mind, we determined to inject alcohol into peripheral motor nerves with the idea of producing a temporary paralysis of spastic muscles. The operative procedure is to expose the nerves a short distance from where they enter into the muscles, and to inject them with eighty per cent. alcohol.

Between 1924 and 1931, twenty-eight cases of spastic paralysis of legs were operated upon. The desired muscular paralysis was obtained and persisted for three to six months. We believe that this procedure is the method of choice for obtaining relaxation of the spastic muscles, which is the foundation on which successful muscle training of the weaker non-spastic muscles must rest.

* This work has been carried on in conjunction with Dr. Carl T. Harris.

† Presented at the Annual Meeting of the American Orthopaedic Association, Toronto, June 17, 1932.

We recognize that other procedures, such as the division of contracted tissues for the overcoming of deformities, are sometimes necessary adjuncts; but we insist that muscle training, carried on by a competent staff for months or years, is the fundamental agent in helping these unfortunate children.

If this be so, then operations should not be performed upon children who are too young or too feeble-minded to cooperate with those who would help them.

Since it is not practical to use a measuring stick to evaluate the end results in this type of case, I shall not bore you with statistics but merely say that our end results are very much better following alcoholization of the peripheral nerves than after any other method with which we are familiar.

1. Ryerson, E. W.: Cerebral Spastic Paralysis in Children. J. Am. Med. Assn., XCVIII, 43, 1932.

SUMMARY OF DISCUSSION

Dr. W. B. Carrell, Dallas, Texas, after experience with perineural alcoholization in the brachial plexus and the sciatic nerve, would be fearful of recurrences which are to be expected after a Stoffel operation only in proportion to the percentage of nerve sectioned.

Dr. Fitch, in closing, admitted the certainty of recurrence, claiming, however, that the paralytic interval permits muscle training to better advantage, and that one may divide too few or too many nerves in a Stoffel operation, either of which is a misfortune.

LEG LENGTHENING WITH NEW STABILIZING APPARATUS

BY EDWARD J. HABOUSH, M.D., AND HARRY FINKELSTEIN, M.D.,
NEW YORK, N. Y.

Of the important recent advances in orthopaedic surgery, none have aroused greater interest than bone-lengthening procedures. The literature on this subject reveals the fact that considerable experimental effort has been expended in attempts to successfully lengthen shortened bones. Among others, such names as Codivilla, Freiberg, Magnuson, Ombredanne, Putti, Steinmann, and Kirschner appear prominently in medical publications. To Abbott, however, is due the greatest credit for devising an improved operative technique, and an ingenious apparatus for maintaining the bones in position during the lengthening procedure. With the appearance of his first article in the January 1927 issue of *The Journal of Bone and Joint Surgery* (*IX*, 128), an added impetus was given this most intriguing subject.

During the past few years, over twenty-five operations for bone lengthening by the Abbott method have been performed at the Hospital for Joint Diseases.* The accompanying chart is a detailed description of only seventeen of these cases which were observed over a sufficient length of time to warrant consideration.

In reviewing the cases shown in Table I, the following complications were encountered:

1. Anterior and medial angulation during the bone-lengthening process.
2. In no case was the separation of the fibular fragments equivalent to that of the tibial fragments.
3. Valgus of the foot.
4. Equinus of the foot.
5. Osteomyelitis.
   A. At the site of the tibial osteotomy.
   B. At the site of the pin insertions.
6. Delayed union and non-union.

A more detailed study of these complications emphasizes the fact that practically every case showed a certain amount of anterior and medial angulation, in some instances reaching as high as thirteen and one-half degrees. We determined our readings from x-ray plates with the use of a transparent protractor with attached threads for measuring purposes. Even one-half of a degree of angulation could thus be determined. In one of our cases there was twenty-five degrees of posterior angulation. In this case the Carrell three-pin method was employed in the hope of preventing anterior angulation.

* From the Orthopaedic Services of Dr. Leo Mayer and Dr. Harry Finkelstein at the Hospital for Joint Diseases.

TABLE I

Summary of Seventeen Cases

Patient's Initials	Age	Sex	Case No.	Diagnosis	Findings	Operation	Operative Wounds	Date	X-RAYS: Anteroposterior View — Amount of Medial Angulation in Degrees	X-RAYS: Anteroposterior View — Amount of Lateral Angulation in Degrees	X-RAYS: Lateral View — Amount of Anterior Angulation in Degrees	X-RAYS: Lateral View — Amount of Posterior Angulation in Degrees	X-RAYS — Amount of Separation of the Tibial Fragments in Inches	X-RAYS — Amount of Separation of the Fibular Fragments in Inches: At the Site of the Proximal Osteotomy	X-RAYS — Amount of Separation of the Fibular Fragments in Inches: At the Site of the Distal Osteotomy*	X-RAYS — Special X-Ray Remarks	Complications	Additional Data
O. B.	15	M	31378	Old poliomyelitis	Two and a half inches shortening of the left tibia	2–4–31 Abbott lengthening, four-pin method	Two small granulating areas over tibial incision	2–14–31 2–17–31 2–18–31 2–27–31 3–20–31 5–14–31	2.0 0 3.0 4.0		12.0 19.0 11.0 13.5 5.0 0		1.0 1.0 1.5 2.125 2.75 2.5	0 Obscure Obscure Obscure .875 .625	.375 Obscure Obscure 1.0 .375 1.0	No callus	Flexion contracture of the knee	Proximal pin removed 4–25–31 Remaining pins 5–13–31
F. B.	16	M	27410	Old poliomyelitis	Right pelvis tilted downward one and a half inches, and three inches of shortening	4–30–30 Abbott lengthening, four-pin method	Healed	5– 8–30 5–26–30 6–10–30 6–10–30 6–20–30 9– 9–30 1–16–31	 7.0 4.5 7.0 10.0	1.5 2.0 1.5	3.0 3.5 2.0 13.5	 5.0 0	.555 2.0 3.125 2.0 2.125 1.122		.312 1.75 1.875 1.5 1.125 1.0	Bony union	Extreme equinus of the foot	6–16–30—three pins removed 6–30–30—one pin removed
S. Z.	17	F	29908	Old poliomyelitis	One and three-quarters inches of shortening of right lower extremity	10–15–30 Abbott lengthening, four-pin method 12–10–30 Removal of necrotic bone from the tibia	No data on the chart	10–27–30 11– 4–30 11–25–30 12– 8–30 12–15–30 12–27–30 12–13–30	0 0 2.5 9.0 6.0 7.5	1.0	2.0 6.0 8.0 5.0 10.0 0 7.0		.25 1.375 2.625 2.375 1.5 1.5 1.5		0 .875 2.0 1.75 1.25 1.0 87.5	Slipping of fragments No callus	Osteomyelitis of the tibia Delayed union	Pins removed 12–10–30
M. L.	13	F	29990	Old poliomyelitis	Two and a half inches shortening right lower extremity	10–29–30 Abbott lengthening four-pin method	Healed	11–10–30 11–22–30 12–13–30 4–24–31	2.0 3.5 0		6.0 11.0 1.5		.875 2.25 1.75		.25 1.0 .375	Excellent alignment Bony union		
J. M.	16	M	27083	Old poliomyelitis	Two inches shortening left leg	4–19–30 Abbott lengthening, four-pin method	Tibia denuded for an area about 3 inches long and 0.75 inches wide	4–24–30 4–25–30 5– 5–30 5–12–30 6–20–30 9– 8–30 8– 8–30	1.5 7.0 8.0 6.0 10.0		5.5 7.5 3.0 0 5.0 5.0 5.0		1.5 2.0 2.0 1.125 1.125 1.0		.75 Obscure Obscure .75 0.25 Obscure	Medial displacement .31 inches Callus formation	Osteomyelitis of the tibia	Pins removed 5–9–30
B. W.	12	M	33498	Old poliomyelitis	One inch shortening left lower extremity	6–17–31 Abbott lengthening with an adjustment controlling second and third pins	No data on chart	6–22–31 7– 1–31 7– 7–31 7–12–31 7–21–31 8–17–31	2.0 2.0 2.0 3.0 6.5 6.0		Obscure Obscure Obscure 3.0 2.5	1.0	0.187 0.75 1.187 1.187 1.5 1.75	0 0.25 43.75 0.75 1.375 0.875	0 0 0 0 0 0	No callus		

TABLE I — *Continued*

					second and third pins		7–21–31	6.5			1.187	0.75	0					
							8–17–31	6.0		Obscure	1.5	1.375	0	No callus				
										3.0	1.75	0.875	0					
										2.5								

TABLE 1 — *Continued*

A. Z.	14	M	31377	Old poliomyelitis	Two and a half inches shortening	3–4–31 Abbott lengthening, three-pin method	Healed	3–14–31	1.5		Obscure	1.0	0	0.75	Distinct callus formation		Pins removed 5–6–31
								4– 3–31	3.0		Obscure	2.125	0	1.5			
								4– 8–31	3.0		0	2.25	0	1.437			
								5–15–31	3.5		3.0	2.25	0	1.5			
								5–18–31									
B. K.	14	M	32902	Old poliomyelitis	Right pelvic tilt and shortening of the right lower extremity	5–14–31 Abbott lengthening with third pin used as suggested by Carrell	Sloughing of skin over medial aspect of shin, exposing bone	5–18–31	2.0		25.0	.312			Medial displacement of the distal fragment	Osteomyelitis of the tibia	
								5–22–31			13.0			0	Anterior displacement of the distal fragment		
								6– 2–31			Obscure	1.5	0.75	0			
								6– 5–31			Obscure	1.625	0.75	0	Tongue broken at base		
								6–22–31				1.75	0.375	0			
								7–20–31			Obscure	1.5	0.625	0			
								10–21–31		4.5		1.25					
								12–18–31		12.0							
D. S.	10	F	32039	Old poliomyelitis	One and one-half inches shortening right tibia	3–18–31 Abbott lengthening, four-pin method 4–19–31 Removal of necrotic bone from tibia	Distal end of proximal fragment found angulated through the wound	5– 9–31	3.0			1.5	0.75		Callus formation Bony union	Osteomyelitis of the tibia	Microscopic section — chronic osteomyelitis 4–29–31 Pins removed 5–13–31
								1–21–32	0	14.0							
L. R.	9	M	28209	Old poliomyelitis	One and a half inches of shortening of the left lower extremity	6–18–31 Abbott lengthening by the four-pin method	Healed	6–26–30	0	0		0.125		0			
								7– 3–30	2.0	3.0		0.437		0			
								7–11–30		2.0		2.125		0.875			
								7–18–30	5.0	2.0		1.75		0.875			
								8–12–30	9.0	0		1.75		Obscure	Good callus formation		
								11– 1–31	7.0								
G. C.	10	M	26653	Old poliomyelitis	Two inches shortening of the left lower extremity	3–10–30 Abbott lengthening by the four-pin method	Healed	3–20–30	0	2.0		1.5		0.312			Pins removed 5–14–30
								4– 8–30	0	5.0		1.75		1.125			
								4–28–30	5.0	6.0		3.187		2.0			
								5–15–30	3.0	0		2.0		1.0			
								7– 1–30	0	0					Callus formation Excellent alignment		
R. M.	23	F	26654	Old poliomyelitis	Two and three-quarters inches shortening of the right lower extremity	1–28–31 Abbott lengthening, four-pin method 11–11–31 Restabilization, right foot 6–8–31 Sequestrectomy, right tibia 3–18–32 Sequestrectomy, right tibia	Area skin necrosis 1.5 inches in length, middle portion of leg	2– 7–31	0	9.0		1.375	0.5	0		Osteomyelitis of the tibia Severe equinus of the foot	Pins removed 3–5–31 Right foot stabilized in 1921
								2– 9–31		7.0		1.25	0.625	0			
								2–11–31		5.0		1.25	0.625	0			
								2–14–31	0	4.0		1.625	0.875	0			
								2–27–31	0	7.0		2.375	1.25	0			
								3–13–31	0	5.0		2.75	1.5	0			
								3–25–31	0			2.625	Obscure	Obscure			
								3–28–31	6.0	5.0		2.0	1.0	0.75			
								6– 6–31	9.0	2.0		2.25	1.0	Obscure			
								1–28–32	0	0							
								9–17–31	9.0						Callus formation		
M. L.	9	F	34509	Old poliomyelitis	Shortening of the right lower extremity	6–18–31 Abbott lengthening, four-pin method	Anterior wound showed a granulating area 3 inches long and 0.5 inch wide	6–22–31	6.0	2.0		0.312	0.625	0.625		Valgus deformity of the foot	Pins removed 9–1–31
								7– 1–31	4.0	Obscure		0.69	0.312	0.625			
								7– 9–31	3.5	4.0		1.375	0.75	.125			
								7–15–31	5.0	3.0		2.062	1.0	.125			
								7–21–31	0	4.0		2.125	1.125	.125			
								8–12–31	2.0	4.0		2.25	1.125	.125			
								9– 1–31	0		5.0	2.25	1.125	.125			

(*Continued on next page*)

TABLE I—*Continued*

Patient's Initials	*Age*	*Sex*	*Case No.*	*Diagnosis*	*Findings*	*Operation*	*Operative Wounds*	*Date*	X-RAYS: Anteroposterior View — *Amount of Medial Angulation in Degrees*	X-RAYS: Anteroposterior View — *Amount of Lateral Angulation in Degrees*	X-RAYS: Lateral View — *Amount of Anterior Angulation in Degrees*	X-RAYS: Lateral View — *Amount of Posterior Angulation in Degrees*	X-RAYS — *Amount of Separation of the Tibial Fragments in Inches*	X-RAYS — *Amount of Separation of the Fibular Fragments in Inches*: *At the Site of the Proximal Osteotomy*	X-RAYS — *Amount of Separation of the Fibular Fragments in Inches*: *At the Site of the Distal Osteotomy**	X-RAYS — *Special X-Ray Remarks*	*Complications*	*Additional Data*
A. D.	10	F	27751	Old poliomyelitis	Two inches shortening chiefly in the right tibia	5–21–31 Abbott lengthening	Completely healed	6– 6–30 6–16–30 2–14–31 11–25–30	0 5.0 7.0 5.0		12.0 4.0 0		1.0 1.0	Obscure Obscure	Obscure Obscure	Firm bony union		
H. G.	13	F	33040	Old poliomyelitis	One and three-quarters inches shortening left lower extremity	5–21–31 Abbott lengthening, four-pin method	Wounds entirely healed	5–23–31 6– 2–31 6–15–31 6–19–31 7–15–31 9– 8–31 10–29–31 8–10–31 12– 9–31	1.5 5.0 5.0 0 0 0 0 0 0		1.0 0 0 0 0 2.0 0 0 0		0.187 1.25 2.25 2.437 2.5 2.5 2.375 2.375	0.375 0.75 Obscure 1.0 1.0 Obscure Obscure	0.25 0.75 Obscure 0.5 Obscure Obscure Obscure	Firm bony union		
F. B.	17	F	26192	Old poliomyelitis	Three inches shortening of right lower extremity	3–5–30 Abbott lengthening, right tibia 2–14–31 Sequestrectomy, right tibia	Superficial wound mid-tibia, one and a half by one-half inch by one-quarter inch, with grayish necrotic tissue at base which was excised	3–20–30 3–12–30 4– 8–30 5– 8–30 5–12–30 5–31–30 9–30–30 8–29–30 1–20–31 7–25–31 8–25–31	0 0 0 7.0 5.0 3.0 9.0 12.0 0 8.0 11.0		Obscure Obscure 13.0 2.5 0 1.5 7.0 0 0 0		1.562 0.75 2.75 2.75 2.75 2.75 1.5 Obscure	1.5 0.5 1.875 2.0 2.0 Obscure Obscure Obscure		Medial displacement of the distal fragment Medial displacement of the distal fragment No callus present Callus present Chronic osteomyelitis with sequestrum	Osteomyelitis of the tibia, both middle and distal aspects Non-union of the tibia	
K. B.	16	F	31475	Old bilateral ankylosis following epiphyseolysis	Shortening left lower extremity 1.75 inches	2–18–31 Abbott lengthening, four-pin method 3–9–32 Albee bone graft, left tibia, for non-union	Area of pressure necrosis over the proximal fragment	2–27–31 3– 7–31 3–20–31 4– 8–31 5– 4–31 5– 9–31 7–14–31 9– 8–31 10–17–31 1– 6–32	5.0 13.5 3.0 8.0 12.0 5.0 7.0 15.0 16.0 12.5		14.0 11.25 12.0 0 0 0 0 0 0		1.0 1.375 1.75 2.5 1.625 1.625 1.375		0.5 1.0 1.25 1.75 1.25 1.0 0.75	Slight callus present Slight callus formation	Non-union of the tibia	Pins removed 5–18–31 Pathological specimen removed at operation for non-union 5–9–32 Report, fibrous tissue Slight tendency of the tibia to angulate anteriorly

*In several cases the fibula was osteotomized at two different levels.

It is our opinion that anterior angulation is due to rotation downward of the distal fragment, while the proximal fragment remains fixed. This point may well be illustrated by one of our cases, in which, despite an increasing flexion deformity at the knee tending to depress the distal end of the proximal fragment, the distal fragment remained angulated.

It has been our experience that the Abbott apparatus does not sufficiently control the angulation during the lengthening procedure because the pins bend. This is particularly true of the lower pins, since there is a greater distance between the leg and lower movable blocks which affords the pins a longer lever arm for bending. In using the Abbott apparatus with angulation developing, one may readily appreciate how the proximal pin in the distal fragment would tend to exaggerate the deformity with each additional turn of the nut.

The Abbott apparatus also permits medial angulation. We have observed that, while the pins and lower movable blocks are parallel at the time of insertion, they do not remain so during the lengthening process. Resistance by the soft tissues causes the distal fragment of the tibia to angulate medially. In turn, the lateral ends of the lower pins and lateral movable block are checked temporarily, while the medial ends of the pins and movable block continue to move downward. The slack is taken up by the spring between the lateral movable block and nut. If uncorrected, the degree of medial angulation will be accentuated.

After careful measurements from x-ray plates following bone-lengthening operations by the Abbott method, the authors noted that in no case was the separation of the fibular fragments equal to that of the tibial fragments. This was primarily due to the fact that the pins were inserted only into the tibia, and secondarily to the resistance offered by the periosteum of the tibia, interosseous membrane (even though they were divided), undivided lateral compartment fascia, muscles, and other fascial attachments to the fibula. Dividing the periosteum of the tibia and interosseous membrane at the same level, over the site of the tibial osteotomy as advocated by Abbott, does not release the tension upon either osteotomized tibial or fibular fragments. The fibular fragments are bound to each other by the interosseous membrane, because it is divided above the site of the fibular osteotomy. This is also true of the periosteum covering the distal fragment of the tibia for it, too, is bound to the upper fragment of the fibula by the interosseous membrane between the fibular osteotomy and the level at which the periosteum was divided.

Because of this discrepancy in the separation of the fibular and tibial fragments, the tip of the external malleolus is higher than under normal circumstances; this places tension on the fibulocalcaneal, talocalcaneal ligaments, and peroneal muscles, resulting in a valgus deformity of the foot. This occurred in two of our cases. Another factor favoring valgus deformity can be ascribed to medial angulation of the distal fragment of the tibia, the upper end of which is inclined medially while the lower end is displaced laterally.

Equinus deformity of the foot occurred in two of our cases, one of which required a subsequent restabilizing operation. In one of our unreported cases, the plantar flexor muscles were so resistant that a right-angle position of the foot was maintained only at the expense of an area of pressure necrosis on the sole of the foot. It is also important to bear in mind that in cases of anterior angulation, the lower end of the distal fragment of the tibia is displaced backward, thus favoring equinus deformity. It is also possible that the undivided posterior investing deep fascia likewise may be a restraining force favoring equinus deformity. In a certain percentage of cases of leg lengthening, the Abbott apparatus does not control the position of the foot. Even Abbott accepts this stand and "considers it unwise" in dealing with the cases of infantile paralysis to stabilize the foot before the operative lengthening, because, in a number of cases in which the foot was previously stabilized, restabilization had to be carried out at a later date.

Osteomyelitis at the site of the tibial osteotomy occurred in six of our cases, five of which were due to anterior buckling of the tibial fragments. It is evident that an increasing anterior angulation may produce pressure necrosis of the overlying tissues, exposing bone, and thereby converting a presumably simple into a compound fracture. In the case treated by the Carrell three-pin method, in order to avoid anterior buckling, not only was there twenty-five degrees of posterior angulation, but also osteomyelitis of the tibia due to pressure necrosis of the overlying skin. The force exerted by the pin was so great that a fracture of the proximal tongue of bone also ensued. Abbott reports a similar experience.

Osteomyelitis at the site of pin insertion occurred in one case. As a result of this complication, we have adopted the use of thin Kirschner wire as a substitute for the heavier pins.

Delayed union was present in four cases. In one the fragments were displaced during the final application of a plaster cast before solid union had occurred; another was the case previously mentioned, in which there was a fracture of the proximal tongue of the bone. Both of these ultimately united. Two other cases resulted in non-union, necessitating subsequent bone-grafting operations.

Although delayed union and non-union may be attributed to many causes, it is the opinion of the authors that two of the contributory causes can be ascribed to:

(1). The improper alignment of the fragments.

(2). The severance of the periosteum at the point of osteotomy of the tibia as recommended by the Abbott plan.

While the periosteum is accepted by some as being only a limiting membrane, lacking in osteogenetic function, there is no doubt of the osteogenetic power of its deeper stratum.

In analyzing these various complications, it was clearly evident, therefore, that in the Abbott method of leg lengthening the main difficulties encountered by the authors were due to the following causes:

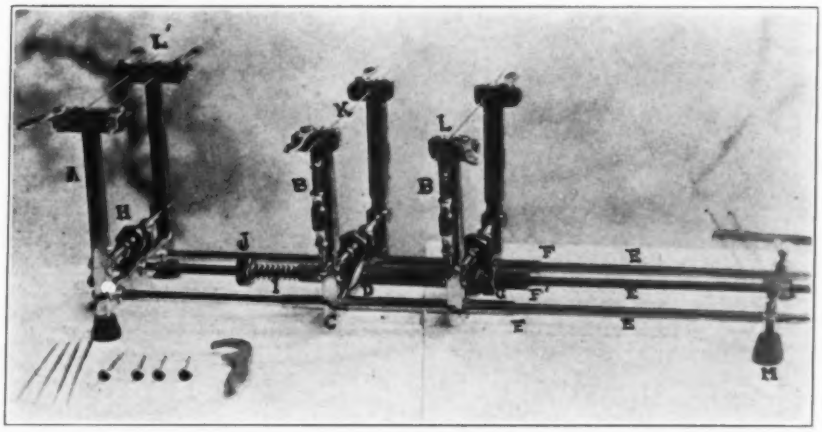

FIG. 1

A. Proximal uprights.
B. Middle and distal uprights which are adjustable vertically.
C. Hinge joints.
D. Cross-bars.
E. Longitudinal rods.
E'. Threaded longitudinal rod.
F. Steel tubes which ride freely on longitudinal rods.
F'. Threaded steel tube which rides freely on the threaded longitudinal rod.
G. Nuts on each side of distal cross-bar which fix it.
H. Turnbuckle screw arrangements which spread the lateral uprights and place tension on the Kirschner wires, *K*.
L. Single clasps for holding Kirschner wire.
L'. Double clasps for Kirschner wire.
I. and *J*. Spring and nut for lengthening.
M. Rubber peg.

(1). That the fragments of the osteotomized tibia could not be maintained in proper alignment with absolute certainty.

(2). That the separation of the fibular fragments was not equal to that of the tibial fragments.

(3). That insufficient attention had been given to the resistance offered by such soft-tissue structures as fascia, interosseous membrane, and periosteum.

(4). That proper position of the foot could not be maintained, and, finally,

(5). That too long a period of time elapsed in the average case before complete bony union occurred.

In an attempt to overcome these difficulties, various investigations, together with cadaver dissections, were undertaken. In the course of these experimental studies, certain difficulties were encountered, which could be directly attributed to the resistance offered by soft-tissue structures. Although all soft tissues yield to a certain extent when traction is applied, fascia yields with great resistance. This was definitely proved by Gratz who demonstrated that, while it has an elasticity range, its tensile strength is that of steel wire from a standpoint of specific gravity. If undivided, it not only resists much of the force used in lengthening, but tends to angulate the distal fragment, for the reason that in the leg the

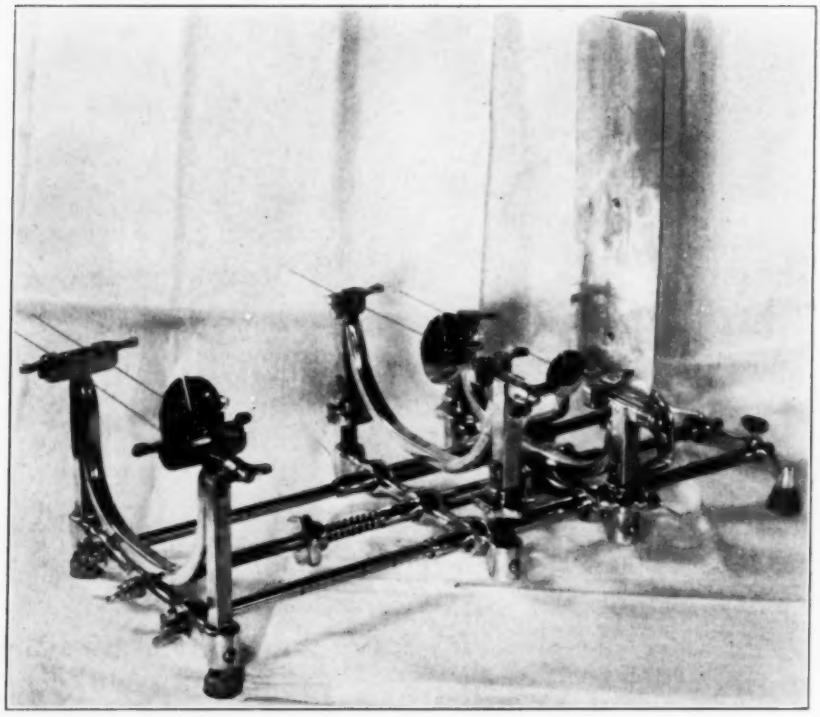

FIG. 2

In the latest model the uprights and cross-bars are fixed, the hinge joints and turnbuckle screw arrangements for spreading the uprights having been eliminated. The wire is made taut by a turnscrew in line with the wire. For controlling the medial angulation we have adopted the use of shields that are attached to the pins on each side of the leg. These shields also prevent the leg from shifting on the wires.

tibia is eccentrically placed, the soft tissues being mainly posterior and lateral. In all probability, the severe pains occurring during the lengthening process, a rather constant feature in this series of cases, were due to the tension on the muscles by the undivided, taut fascial membranes from which some of the muscles derive their origin. Abbott, in his latest contribution, evidently has realized the importance of this procedure, for he likewise advocates the division of the deep anterior fascia, the anterior and posterior fibular intermuscular septa, in addition to division of the interosseous membrane.

The ultimate result of these investigations led to:

(1). The devising of a special stabilizing apparatus by means of which the osteotomized fragments could be controlled at will, with the tibia and fibula maintained in the same relationship as exists normally so as not to disturb the mortise of the ankle, and with the foot held in proper position during the lengthening process.

(2). The use of Kirschner wires instead of the heavier pins.

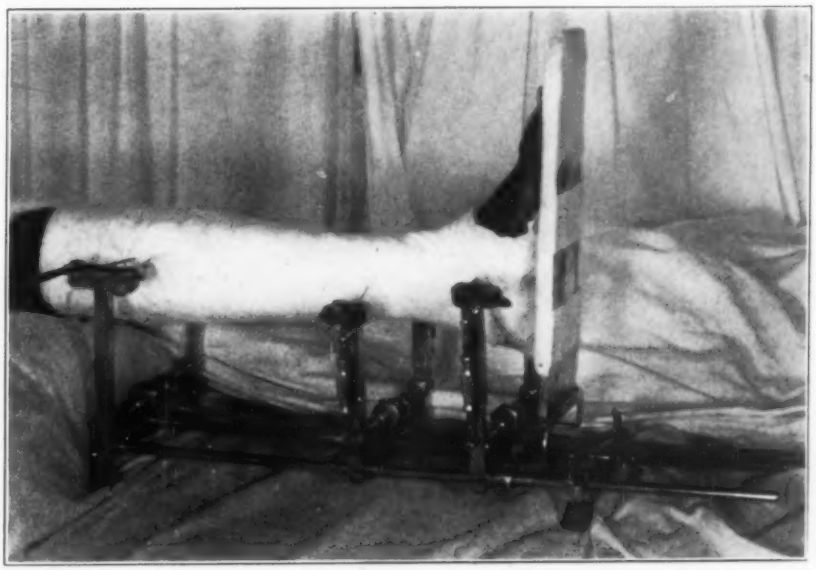

FIG. 3

Leg during the lengthening process.

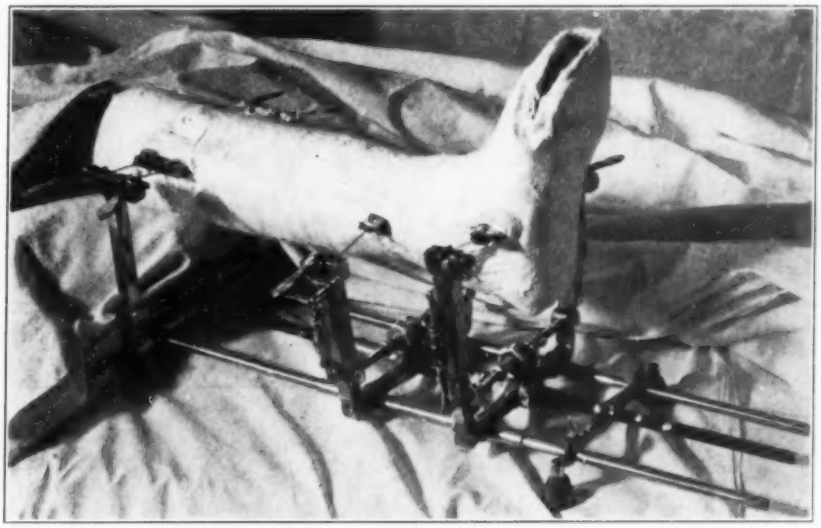

FIG. 4

After the desired lengthening has been procured a plaster bandage is applied. This is done with great ease while the limb remains in the apparatus, as there are no obstructing longitudinal rods. Clasps and longitudinal steel shafts to retain the separation and tension on the wires are incorporated within the bandage.

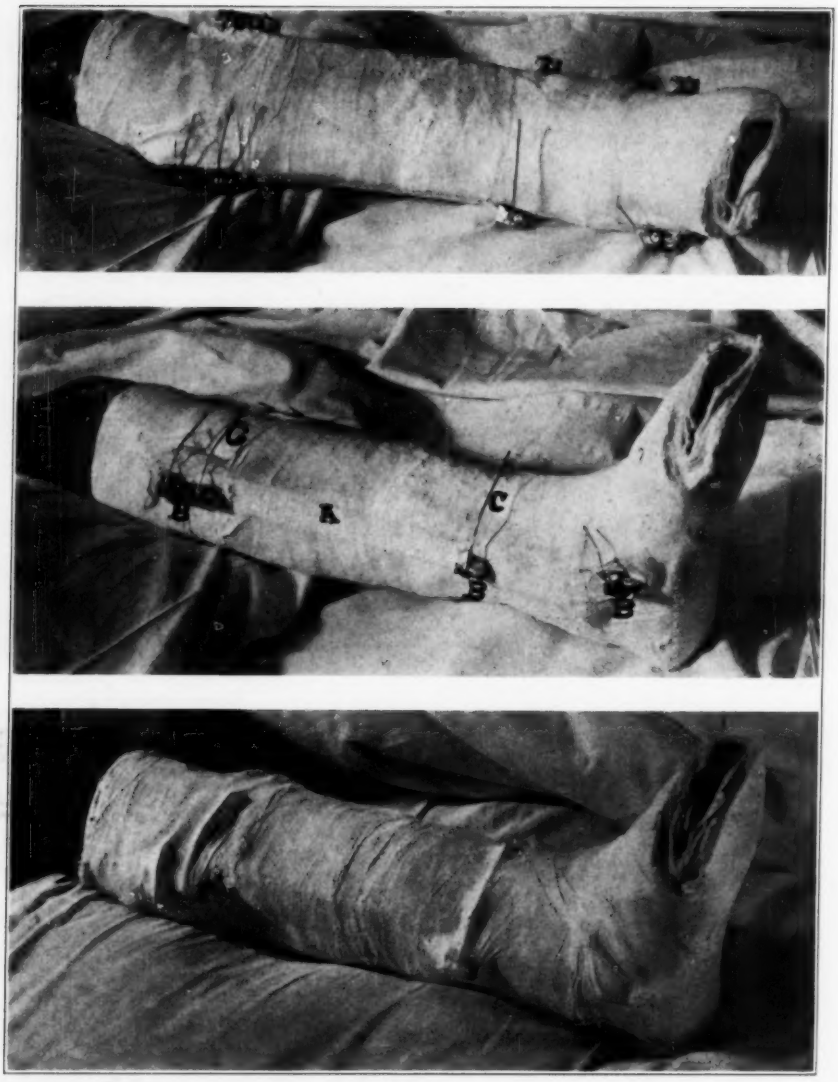

FIG. 5

The limb is removed from the apparatus after the plaster has been allowed sufficient time to dry. To further insure against slipping of the wires they are bent over the clasps and an additional few turns of plaster bandage are applied.

A. Longitudinal steel shaft.
B. Clasps for maintaining tension on wires.
C. Kirschner wires bent over the clasps and plaster.

(3). Insertion of one pin into the distal fragment of the tibia and one into the os calcis. This insures better control and alignment of the fragments in that it creates a shorter lever arm for the angulating forces and a longer lever arm for the opposing forces,—such as, the overlying tissues, skin, and pin. It also controls the position of the foot.

(4). Certain definite changes in the technique of the operation,—such as a more thorough division of the fascia, interosseous membrane, and complete circumferential division of the periosteum of the tibia and fibula, all at the same level, in a non-binding zone at the point of fibular osteotomy.

In addition to the transverse incision of the interosseous membrane and complete circumferential division of the periosteum of tibia and fibula, we incise transversely the entire lateral peroneal compartment fascia, the deep anterior and posterior investing fascia, and the two fascial partitions which divide the posterior osteofascial compartment. This is all accomplished at the same level about two inches above the tip of the external malleolus. No difficulty is here encountered, for the muscles in this region approach their tendinous insertions and are bound by a very loose connective tissue called paratenon. By osteotomizing the fibula at the same level, the fragments are more easily separated, since every restriction has been overcome. This is also true of the periosteum of the tibia and, by dividing it at the same level instead of at the site of the tibial osteotomy, as suggested by Abbott, the periosteum above is preserved *in toto*, so that it may be used to amply cover the gaps of the tibia resulting from the elongation process, thus favoring a more rapid deposition of callus and hastening bony union. Another advantage of this change in technique is that a sleeve of periosteum is created into which the distal fragment of the tibia can glide.

THE APPARATUS

The apparatus specially designed by the authors consists of three pairs of lateral uprights, each of which is attached at its lower end by a hinge joint to a horizontal cross-bar. The upper ends of the uprights are T-shaped. The horizontal part of the T of each of the proximal uprights has two clasps for gripping the Kirschner wire. Each of the second and third pairs of uprights holds one wire; while the proximal pair of uprights is fixed, the lower two are adjustable vertically for controlling anterior angulation of the distal fragment. The distal pair of uprights is lower than the other two for receiving the pin which inserts into the os calcis. To the proximal cross-bar are fixed three longitudinal rods, twenty-one inches long, at right angles to it. The center

FIG. 6

A walking iron is incorporated into the plaster and the patient is immediately allowed to walk.

This further stimulates the deposition of callus and hastens bony union.

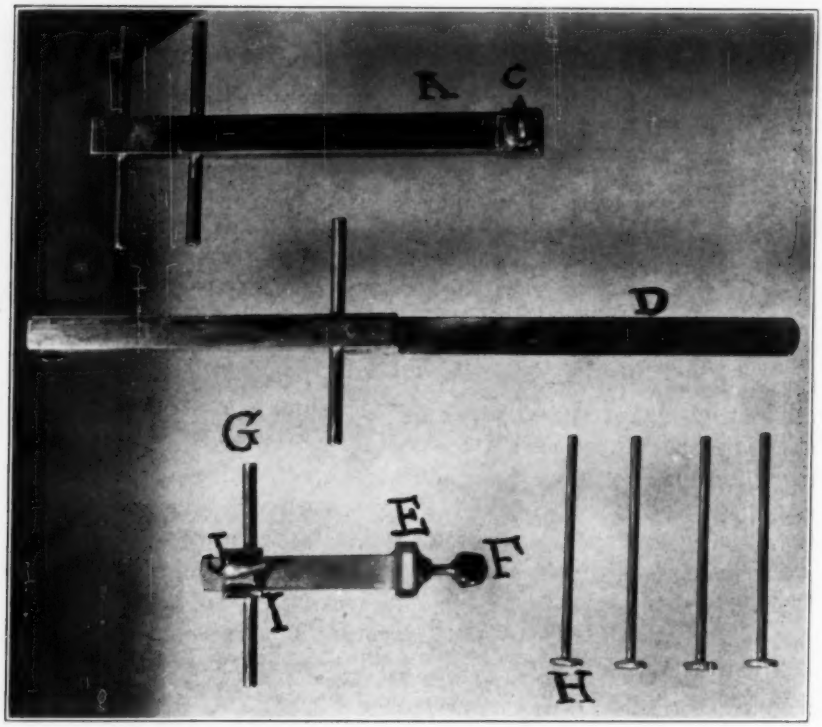

FIG. 7

A. Proximal part of guide.
B. Distal part of guide that telescopes into proximal part *A*.
C. Turnscrew which fixes the telescoping parts *A* and *B*.
E. Vertical shaft that moves freely on *D*, and turnscrew *F* for fixing shaft in the desired position.
I. Carriage holding cylinder for pin inserted into the os calcis. This moves freely on shaft *E* and is fixed by turnscrew *J*.
G. Cylinders for pins.
H. Tubes for Kirschner wires. These telescope into cylinders.

rod is threaded. Three steel tubes, seven inches long, carry the second cross-bar to which they are fixed and move freely upon the rods. The center tube is threaded and has two threaded nuts which fix the third cross-bar, one on each side. There are three holes in the third cross-bar which permit it to move freely on the tubes, making the distance between the second and third cross-bars adjustable, thus creating a freely movable carriage, holding the lateral uprights in a fixed parallel manner. Tension of the Kirschner wire is procured through the lateral uprights by means of a turnbuckle screw arrangement between the uprights. By fixing the turnbuckle screw arrangement to the cross-bars, lateral stability of the uprights is secured. Lengthening is procured by a nut and spring on the center rod between the first and second pairs of uprights. Distal to the moving carriage on the three rods is a cross-bar which may be made fast by turnscrews. At each

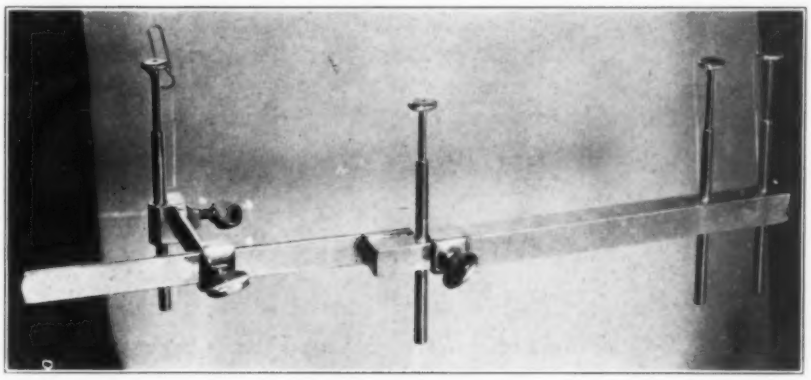

FIG. 8

Guide assembled and ready for use.

end is a rubber peg. The proximal cross-bar is also supplied with rubber pegs, one at each end. These pegs are all of equal length, so that the apparatus may rest on any flat surface. To the lower end of the movable carriage is attached a splint to support the forefoot and toes.

We subsequently modified the apparatus.

The distance between the first two pins is fixed. Between the proximal pins and pin three, as well as between pin three and pin four, the distance is adjustable. Tube for pin four is made adjustable in a vertical direction. For the Kirschner wire removable tubes were made that fit into the guide. This makes it applicable for either pins or wires.

DESCRIPTION OF THE OPERATION

On the lateral aspect of the leg, just above the subcutaneous surface of the fibula, through a three-inch incision, the deep investing fascia of the lateral compartment is exposed. A longitudinal slit is made into the roof of the lateral compartment fascia and in the order given the following structures are divided:

1. Deep investing fascia of the anterior and lateral compartments.
2. Anterior fibular septum.
3. Posterior fibular septum.
4. Periosteum on the lateral surface of the fibula together with the floor of the lateral compartment fascia.
5. Posterior investing fascia and two fascial partitions which divide the posterior osteofascial compartment.
6. Lengthening of the tendo achillis by the Hoke method.
7. Periosteum on the medial surface of the fibula, interosseous membrane, and transverse incision of the periosteum on the lateral and under surface of the tibia.

These structures are all divided at the same level, about two to three inches above the tip of the external malleolus. In the same plane, through the same incision, the fibula is osteotomized obliquely.

The skin is not only pulled toward the center of the leg, but also toward the crest of the tibia, and with our special guide through stab incisions two wires are driven into the proximal end of the tibia, one into the lower end, slightly below the division of the periosteum on the lateral surface of the tibia, and one into the os calcis. An electric drill is used and the wires are driven through with great ease and rapidity.

The apparatus is applied and a slightly curved, seven-inch incision is made through skin, superficial fascia, and periosteum, exposing the tibia. In the lower end of the wound where, on the lateral surface of the tibia, the periosteum had been transversely incised, it is now completely divided and entirely stripped from the tibia for a distance of about three inches. Above this point on the anterior aspect of the tibia the periosteum is stripped sufficiently to permit the longitudinal bone cuts.

The authors consider this change in technique of the greatest importance, since it not only entirely eliminates the resistance of the periosteum, but also preserves it *in toto* to amply cover the gaps in the tibia produced by the elongation process, where its osteogenetic stimulation is most necessary; this favors the more rapid formation of callus and thus hastens bony union. Should the periosteum of the tibia be divided at a level independent of that of the osteotomized fibula and at which all the fascial structures were divided, the periosteum of the tibia would be held by the fascial structures between their levels of division. Should a higher level be chosen, the muscles deriving their origin from these fascial structures would increase the resistance to the lengthening process and cause pain.

The tibia is osteotomized so that the tongue on the distal fragment is made to overlay the tongue on the proximal fragment. The longitudinal bone cuts are made four inches long, and the lower cross cut of the tibia is three inches above the level at which the periosteum was divided. This gives a four-inch tongue of bone which allows for three inches lengthening and one inch overlap.

A drain to prevent postoperative swelling of the foot is inserted into the lower end of the wound which is closed in layers. The drain is removed in twenty-four hours.

SUMMARY

We believe that by the use of our apparatus, Kirschner wires instead of the heavier pins, the insertion of a wire into the os calcis and one into the distal fragment of the tibia, more thorough division of the fascia, division of the interosseous membrane, and complete circumferential division of the periosteum of the tibia and fibula, all at the level of the fibular osteotomy in a non-binding zone, better control and alignment of the fragments is maintained; therefore, osteomyelitis is less apt to occur, the same relationship between the tibial and fibular fragments is assured during the lengthening process, and the foot is held in a more normal position.

The apparatus is designed to rest on any flat surface so that it is no longer necessary to suspend the limb from an overhead frame or tie the

patient to a bed during the lengthening. Plaster may also be readily applied with great ease while the limb remains in the apparatus, so there is no danger of slipping of the fragments; this also permits the patient to begin walking at an earlier date.

By the various changes in the technique of the operation, not only is the resistance of the fascial structures entirely overcome, thereby diminishing the amount of pain to the patient caused by the lengthening process, but also the periosteum is preserved so that it may amply cover the gaps in the tibia resulting from the lengthening process.

The cases that have been treated by this new method form the basis of a paper that will be published at some subsequent date.

In concluding, the authors wish to reiterate the fact that credit for developing the bone lengthening procedure in this country rightfully belongs to Abbott and his coworkers, and that the intention of this contribution is not in a spirit of criticism, but rather to emphasize the importance of certain additional technical and mechanical features, which in the authors' hands have reduced the number of complications previously encountered.

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A TECHNIQUE FOR THE OPERATIVE CORRECTION OF BOW LEGS

BY CHARLES W. PEABODY, M.D., DETROIT, MICHIGAN

It may be accepted that after a certain age limit, or in the presence of marked sclerosis, or in the case of severe saber-shin deformities, the correction of bow-leg deformities by osteoclasis is not feasible and resort must be had to open operation. In this event the usual method is simple transverse osteotomy. When the deformity is considerable and especially when, as is usually the case, the deformity represents a triple one of lateral bowing, anterior bowing, and torsion, the consequent adjustment at the site of division of the tibia leaves a minimum of contacting bone surface —really only an edge or a point contact—with extreme instability; and the maintenance of any apposition till fixation dressings are in place is precarious. This, coupled with the fact that the bone division is made through an area of sclerosis, avascular and often almost eburnated, has made the healing process slow, with delayed union not infrequent and non-union often reported.

Cognizant of this situation, Schwartz advocated the excision of such a wedge-shaped or cuneiform bone segment as would provide full-width apposition of bone surfaces after correction of deformity. The slight resultant shortening, however, leaves enough slack so that maintenance of apposition is rather difficult, as is also the determination of the exact amount of resection which will correct all three deformities.

Even more difficult, in a sclerosed, curved, and twisted bone, is the production of multiple longitudinal lines of osteotomy, that will render it sufficiently plastic to permit complete realignment, as recommended by Haas. Another method that has been advocated,—namely, reducing the entire shaft subperiosteally into a mass of small bone fragments—seems fraught with too great risks to be popular.

Several years ago, in the readjustment of a malunited oblique tibial fracture, it was observed that a simple swiveling motion of the two fragments had resulted in angulation in two planes, plus torsion. This fact suggested that by making a long osteotomy in the proper plane, and with the necessary degree of obliquity and swiveling the two fragments on each other, a triple deformity would be corrected with ensuing wide apposition of cut surfaces that would extend in a rachitic bone beyond the area of maximum sclerosis, and so would favor prompt repair. If the deformity were mainly of the saber-shin type, the oblique osteotomy would be nearly in the sagittal plane, and as long as possible; if mainly a varus or valgus, in nearly the coronal plane. If a considerable element of torsion prevailed in the deformity, the osteotomy would be less acutely oblique, so that the swiveling motion should add more of a rotation element. If the deformity included anterior as well as lateral bowing, the cut would be somewhere

FIG. 1

FIG. 1. M. S. Extreme saber shins or pure anterior bowing. See Fig. 2.

FIG. 2. M. S. After oblique swiveling osteotomy. Ankles restored to normal static plane.

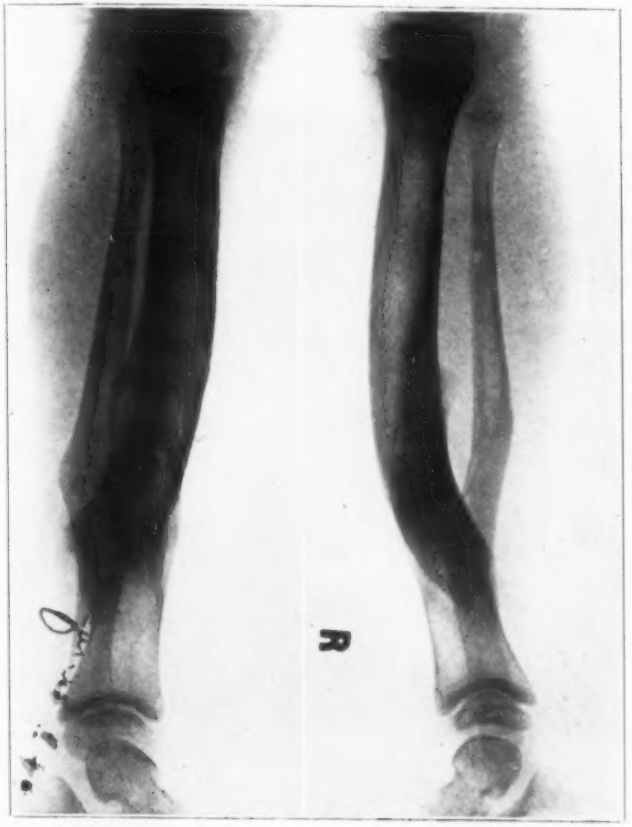

FIG. 2

FIG. 3

F. A. Left leg, lateral view, showing direction of osteotomy after correction of varus bowing plus inversion, by oblique bone cut.

between the coronal and sagittal planes, so that correction of both forms of bowing would result from the swiveling adjustment.

Such a conception seemed to include the following essential desiderata: (1) a plan geometrically simple; (2) the minimum necessary cutting of bone which will still allow realignment in all planes; (3) sufficient apposition or contact of fragments to insure certain and prompt union, with (4) adequate control until fixation dressings are in place.

Acting on the above theory, the writer evolved, three years ago, a procedure which in this period of its application has seemed to meet the above qualifications in a most satisfactory manner and to have been supported by its results in a series of about twenty cases. Experience with it has emphasized, in addition to the simplicity of the operative technique, the following definite advantages:

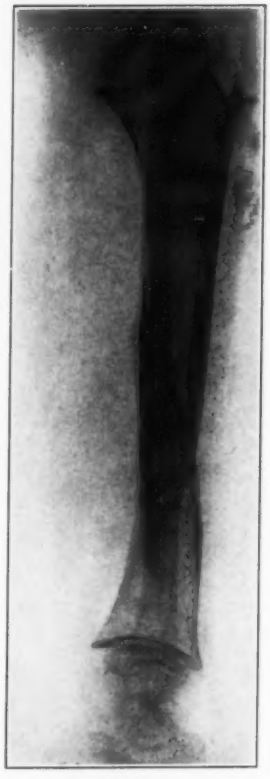

FIG. 4

F. A. Right leg, lateral view, showing swiveling in plane to include correction of anterior bowing as well as torsion and varus.

After the osteotomy, there are wide contacting surfaces of both cancellous and cortical bone, held in apposition by ligature, and finally adjusted to the desired position of correction as the plaster dressings harden, eliminating the uncertainty of eventual good contact and apposition.

As the two fragments constitute inclined planes or wedges in apposition, the circular approximating ligature prevents overriding and shortening.

No periosteal reflection is necessary with very little expected interference with this part of the bone circulation.

The line of osteotomy, instead of being restricted to the dense and sclerosed area at site of maximum deformity, extends well into normal bone areas above and below.

These considerations all probably have some part in the unusually rapid consolidation or healing that has been observed, and in the apparent strength of the healed fracture at an unusually early date. In about half the cases the plasters have been changed for observation at the end of two weeks. In every instance sufficient consolidation was found to have occurred to give the impression of union and to indicate that it would have been difficult to change the position except under an anaesthetic. After two weeks more in plaster, all splinting was discontinued, freedom of the bed allowed, and massage given for another two weeks when walking was started. Pain and tenderness at operative area was apparently not present and all cases proved the completeness of union by the absence of any subsequent deformity, observation on most having continued up to present time, with about half of the total series now at least two years postoperative.

DETAILS OF OPERATION

The middle third of the tibia is exposed through a curved incision, the belly of which lies over the extensor muscles, and under the mid-point of which the fibula may be exposed when indicated. By more or less blunt dissection the shaft of the tibia is freed from the soft parts, the periosteum not being reflected save where it comes away with the muscle attachments. Previous study of leg and films has indicated the plane of osteotomy, and

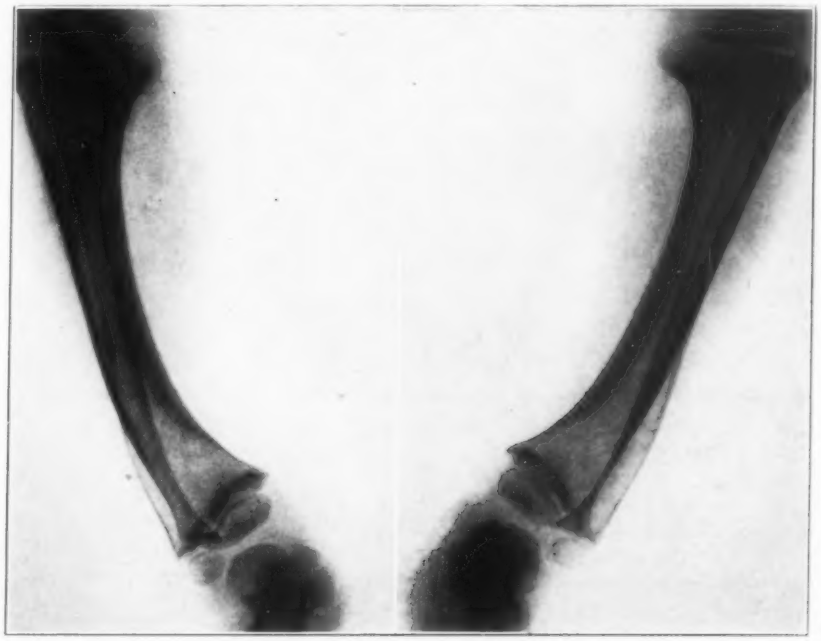

FIG. 5

J. A. Original condition including high-grade varus, considerable torsion in inversion, and moderate anterior bowing.

FIG. 6

J. A. After healing of a moderately long oblique swiveling osteotomy. Note absence of torsion as well as restoration of transverse planes and weight-bearing lines.

the tibia is accordingly cut through in this long oblique plane, using a wide thin osteotome or the motor saw, following which, as a rule, a manual fracture of the fibula is produced, though with very severe deformity a complete division by osteotomy may be preferable. The cut surfaces of the tibia are then rotated on each other to the degree necessary for correction and the amount of projection of the extreme ends of each fragment is noted. When this is considerable, a little trimming may be done. The fragments are then returned to their original position, a No. 2 plain catgut ligature is passed around both at their mid-point and tied tightly. This insures continued apposition of bone with prevention of any soft-tissue interposition before the final adjustment for correction is made, yet leaves the leg in a plastic state for eventual permanent realignment by swivel movement at the fracture site. After treatment of the other leg in same manner and closure of wounds, a plaster fixation is applied in three segments, one extending from upper thigh to a point below the knee, and a second from toes to a point above the ankle. As these two segments harden, the lower is brought into the desired alignment with the upper, the apposition ligature permitting the swivel motion to take place at the fracture site without separation of the cut surfaces. A few more turns of plaster in the middle complete the fixation dressing.

ELABORATION OF THEORETICAL PRINCIPLE

Inasmuch as the simple statement of the principle of this osteotomy may not leave its actual application to the various types of deformity entirely clear, and as it is necessary to select a proper plane for each type, a more elaborate development of the reasoning may be appropriate.

The following conception has seemed to be the most instructive in working out the operative plan: Assume first a Z-shaped osteotomy such

as would be done in shortening or lengthening a long bone. If the two long cut surfaces were rotated in apposition around an axis perpendicular to the mid-point of these surfaces, a simple angulation would result. If such an osteotomy were done in the sagittal plane of a bone with just an anterior bowing, a posterior angulation could be produced which would compensate for the amount of original deviation. In the same way a pure lateral bowing, such as a varus deformity, would be compensable by an osteotomy done from side to side or in the coronal plane, with production of angulation by rotation of the cut surfaces. It next becomes apparent that, if the osteotomy cut were made in a plane half way between sagittal and coronal, the angulation which could be produced by rotation would be fifty per cent. anteroposterior and fifty per cent. mesiolateral, and would be relatively more of the one and less of the other as the cut deviated either toward the sagittal or toward the coronal plane. Thus would compensation and realignment be obtained in a case of marked anterior bowing plus a little varus or valgus; or, again, in a case of marked varus or valgus deviation, plus a little anterior bowing.

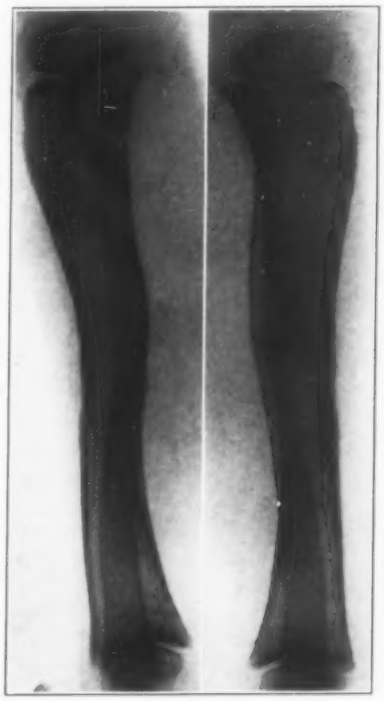

FIG. 7

J. A. Lateral view after healing, showing correction of anterior bowing as well as of other deformities.

Now assume a simple transverse section across the shaft of the bone, with rotation of the lower fragment on the upper around the central longitudinal axis of the shaft; the only resultant deviation would be torsion in inversion or eversion. Should such a section, instead of transverse, be slightly oblique, there would be a lesser degree of inversion or eversion on rotation at the cut, but a new element of angulation or bowing. By the same token, should a Z-shaped longitudinal section be changed to an oblique, an element of torsion or version would appear, increasing relatively as the cut is made more oblique, with progressive decrease in amount of angulation produced as the obliquity approaches the transverse.

So by shading the obliquity of an osteotomy in the various possible directions, various combinations of compensatory deviations may be produced, fitting any case requiring realignment for torsion plus either forward or sidewise bowing, or all three. The writer has but rarely encountered a rachitic bent bone in which there was not some amount of torsion between foot and knee, and with a very long oblique osteotomy a minimum amount

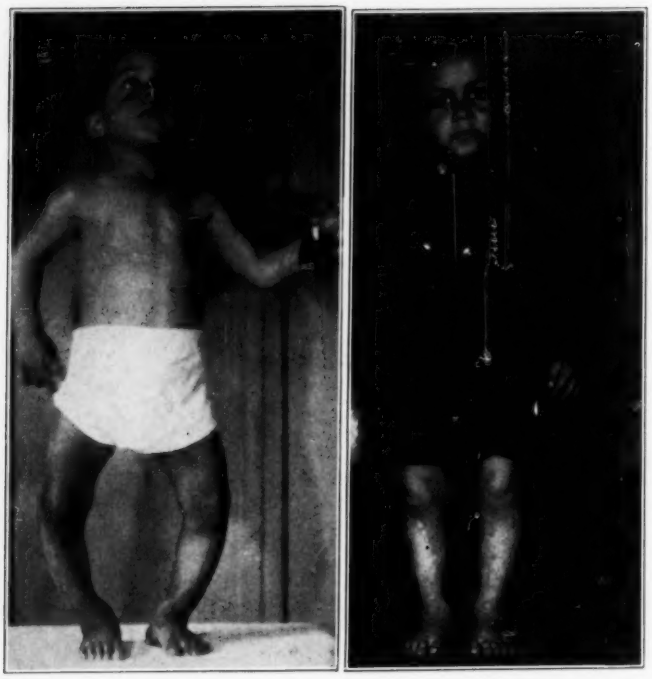

FIG. 8-A FIG. 8-B

J. A. High-grade combination of all deformities—before and after operative correction. See Figs. 5, 6, and 7.

of corrective torsion may be obtained. Conversely, there has not appeared a case of torsion so great that a plane of section sufficiently oblique to correct any accompanying bowing deformities as well is not easily obtained, at the same time extending a distance up and down the bone sufficient to bring the ends of the cut beyond the area of maximum sclerosis. Of course in practice the torsion deformity is never the major one, and is corrected by such a fractional amount of rotation that no geometric calculation of osteotomy for the complicated but rather merely the choice of that one of the two possible oblique shifts,—*i. e.*, that producing inversion or eversion, when the surfaces are rotated to correct the other one or two deformities prevailing.

FIG. 9 FIG. 10

E. P., age thirteen. Sharp varus with painful pseudarthrosis between calcaneal and lateral malleolus.

E. P. After swivel-ing osteotomy.

SUMMARY

A method of corrective osteotomy for the complicated deviations of the rachitic tibia has been described, which seems to include a minimum of operative interference in the bone, universal applicability, adequacy of correction, and prompt and certain consolidation, with notable shortening of postoperative immobilization and convalescence.

The method has been applied to about twenty cases and has been uniformly successful. Complications in the way of wound infection occurred twice, both times on one side only in a bilateral case, and though a low-grade osteomyelitis prevailed, as evidenced by discharge of a small sequestrum, solid union occurred and the sinus closed permanently after a few months with no other treatment than simple dressings. Although complete correction prevailed in all cases of the series, the most striking result seemed to be the rapidity of healing.

THE TENDO PATELLAE

A Roentgen Consideration of Its Length *

BY PAUL O. SNOKE, M.D., LANCASTER, PENNSYLVANIA

The object of this presentation is to show a progressive increase in the length of the patellar tendon after the close of the growth period.

The Dutch roentgenologist, Murk Jansen,[1] after long study of the knee joint, described "patella alta vera",—*i.e.*, a true high-lying patella, which may be productive of discomfort due to pinching of synovial fringes or reflections. It logically follows that if one has a high-lying patella, the tendo patellae must be longer than normal. The length of the normal patellar tendon was not ascertainable from the literature and recourse was made to mensuration of normal roentgenograms.

Our attention was attracted to this matter by the case of an old lady † who fell upstairs, striking both knees simultaneously on a higher step; roentgenograms were secured of both knees and, following a fatal issue, we were permitted an autopsy (Figs. 1 and 2). We found ourselves in posses-

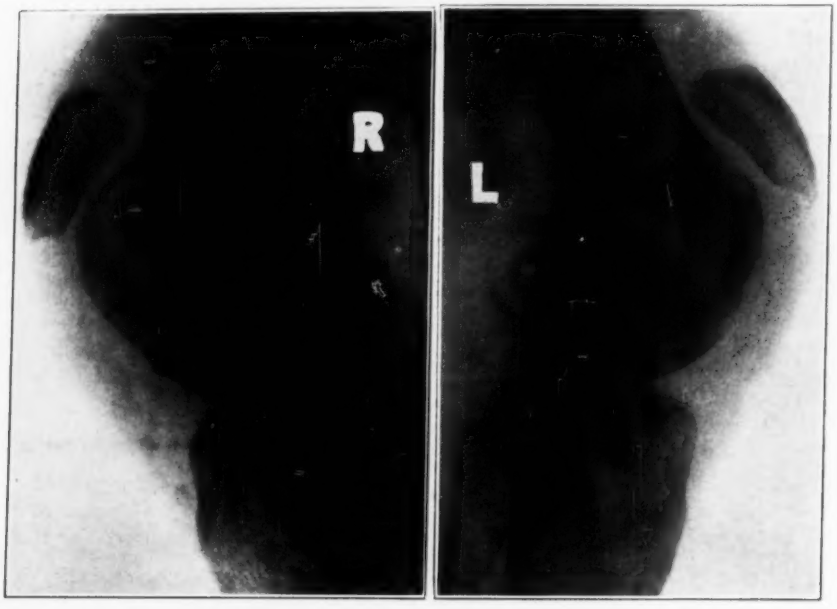

Fig. 1

Note location of patella and shredded patellar tendons. Position of condyles correctly superimposed shown in left knee.

* From the X-ray Department of the Lancaster General Hospital. Dr. Charles Baer rendered valuable assistance in mensuration.

† Referred for diagnosis through the courtesy of Dr. J. L. Atlee, Sr.

sion of roentgenograms of bilaterally ruptured patellar tendons and great diagnostic difficulties in that she had no normal knee with which to make comparisons. We did discover, however, that numerous soft structures were visualized about the knee joints in good lateral roentgenograms and chief among them was the patellar tendon. In order to determine the normal length of the patellar tendon, we set about the mensuration of normal lateral roentgenograms.

FIG. 2

Photograph at autopsy. The ruptured ends of both patellar tendons are visible.

THE LENGTH OF THE PATELLAR TENDON

One hundred normal lateral knee roentgenograms were selected from our files. Boon-Itt's [2] patellar index was calculated and found to be correct. When serious deviation occurred it was frequently due to unrecognized pathology occurring in soft tissue. The internal margin of the tendo patellae was measured from its origin just above the tibial tubercle to the nearest point of the patella. To further check this measurement we measured the distance between the nearest tibial and patellar points.

Variations in the length of the tendon should correspond to age during the growth period, twenty years, after which one would not expect age to affect this structure. The effect of height upon this tendon is not discussed in this paper, because its importance did not occur to us until we began to investigate the matter.

The following table summarizes our findings.

TABLE I

AGE	AVERAGE LENGTH OF TENDO PATELLAE	SHORTEST LENGTH	NO. OF CASES
5–10 years	4.82 cm.	2.80 cm.	4
11–20 years	4.79 cm.	2.77 cm.	27
21–30 years	4.81 cm.	2.78 cm.	19
31–40 years	4.97 cm.	2.74 cm.	16
41–50 years	5.10 cm.	2.75 cm.	12
51–60 years	5.32 cm.	2.81 cm.	8
61–70 years	4.36 cm.	2.57 cm.	8
71–80 years	5.31 cm.	2.51 cm.	6

We can neglect the five-to-ten-year period because of the few cases; in fact the sparsity of cases is regrettable throughout the entire series. One cannot draw hard, fixed rules from one hundred cases; if we had one thousand cases, evenly distributed in age groups, we could be more definite in our statements.

Beginning with the second age group—low limit eleven years—and progressing to the high limit of the sixth age group, the true patellar-tendon measurement increases definitely. The explanation is not difficult. Histologically the tendon is composed of yellow and white elastic tissue, and we should have been able to predict this finding.

At sixty years of age, the factor of hypertrophic arthritic changes arises; the elastic tissue loses its elasticity, and bony outgrowths shorten the measurements. This is more especially noted in the short measurement as the articular cartilage thins with age, permitting the patella to approach the osseous structures.

The figures presented represent averages, but it would be advantageous to know the extremes as well as the means:

The shortest true tendon measured 3.0 cm.

The longest true tendon measured 6.8 cm.

The shortest short measurement was 1.9 cm.

The longest short measurement was 4.1 cm.

We can safely say that any tendo patellae measuring over six and five-tenths centimeters should be regarded with suspicion and carefully examined for continuity of structure.

In our case of bilaterally ruptured tendo patellae the tendon measurement was eight centimeters right, and eight and one-tenth centimeters left, and—of greater importance—the shredded ends of the tendons were visualized. Occasionally the upper end of the tibia deviates from the normal conformation; for this reason we use the short tibial-patellar measurement. In case rupture is suspected, the two measurements should be correspondingly increased; whereas in a deviation from the normal the short measurement will not check.

CONCLUSIONS

We have measured the length of the patellar tendon in a small number of cases, using normal lateral roentgenograms.

A gradual increase in the length of the tendon after the close of the growth period is noted. This is assumed to be due to stretching of elastic connective tissue.

A table with the derived normal lengths is presented.

We feel that in some large center further studies on a larger series of cases should be made.

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A STUDY OF THE BLOOD SUPPLY OF THE LIGAMENTUM TERES AND ITS RELATION TO THE CIRCULATION OF THE HEAD OF THE FEMUR *

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The ligamentum teres has been known since ancient times. Singer states that Hegetor, one of the later Alexandrian medical writers who lived about 130 B.C., recognized the round ligament of the hip joint. The controversy regarding the vascularity of the ligament did not begin until after Paletta's original statement in 1820. Paletta wrote in Latin, which is not available to us. Moser (1892) translated Paletta's statement as follows: "The obturator artery gives off a small branch which passes through the acetabular fossa and divides into two branches,—one for the fossa and one which traverses the round ligament to supply the head of the femur." Since that time the literature has been quite contradictory.

Only a few of the more important papers will be discussed, since Moser (1892), Kolodny (1925), Phemister (1931), and others have published reviews. Hyrtl (1846) declared that the ligamentum teres did not carry nutrient vessels, since injection experiments demonstrated that the vessels in the ligament anastomosed with veins at the junction of the ligament with the head and then passed back through the ligament. In contrast to this view, von Luschka (1865) very definitely states that he never failed to find arteries which made their way through the pores of the fovea capitis into the substance of the head of the femur. No mention is made of the number of specimens examined. Von Luschka also recognized that arteries pass along the synovial membrane and penetrate the bone near the cartilaginous junction. Welcker (1876) investigated the problem by observing the fovea capitis for the presence of pores. He does not state the number of cases examined, but found that in one-third there were no pores, and in the remainder the openings were so small as to be negligible. Welcker also examined children and young adults and found that the openings were either absent or very small. Langer (1878) studied the vascularity of the ligamentum teres by the injection method. In this way he demonstrated an artery in the ligament which passes into the cartilaginous head, and in addition a supply arising from the epiphyseal arteries. An anastomosis occurs between the two systems as soon as the bony nucleus arises. In older children Langer states that injection of the obturator artery proves that the round ligament serves as a conduit by which vessels pass to the

* Presented before the Chicago Surgical Society, April 1, 1932.

head of the femur. Langer fails to state the number of cases observed, but records the following general conclusions: examples in which there are as many as four one-millimeter-sized openings in the fovea capitis, some ligaments which contain no vessels or a number of small vessels, and still other specimens in which the ligament is entirely wanting.

Moser (1892) made serial sections of the ligament and the head of the femur in many stages of foetal life and childhood up to four years. When the ligament first appears it is avascular; but in embryos twelve centimeters long, vessels pass into the head. By the seventh foetal month three to four branches are present in the ligament. Moser considers this supply of much less importance than that which reaches the head through the synovial membrane surrounding the neck of the femur. He further states that he could not be sure that the vessels contained in the ligament were necessary for the ossification of the head. Moser did not carry his studies beyond the fourth year of child life, because he believed that the ligament becomes atrophic at about this age, due to the unfavorable environment in which the ligament finds itself during active life. Moser also examined the fovea capitis for foramina. They were present in about one-half of the cases examined and doubt is expressed as to whether these actually ever contained blood vessels. This fact, plus the delayed appearance, indicates that the ligament is wholly non-essential at all ages and certainly in adult life.

Walmsley (1915) studied the vascularity of the ligamentum teres by two methods. By the use of a hand lens, one hundred ligaments were examined without finding vessels. Whether these bodies were injected or not is not stated. Walmsley observed that many vessels reach the head from the articular margin but none from the ligament. A second method of investigation was to inject the hypogastric arteries and the remainder of the general circulation with different colored solutions. This was carried out in specimens from two children,—one, two and the other, six years old. In both cases the injected material which filled the head came entirely from the vessels entering at the articular margin of the head. A small area of cartilage in the immediate proximity of the attachment of the ligamentum teres seemed to be vascularized. "These results", says Walmsley, "show that the ligament does not convey blood to the head of the femur. Most of the foramina in the fovea capitis are channels of communications of the ligamentous tissue into the cartilage and osseous substance of the bone."

Many clinicians have contributed to the anatomical knowledge regarding the ligamentum teres. A few of these contributors have been Phemister, Kolodny, Santos, and Schmorl. Probably most clinicians feel that the ligamentum teres is of little importance either as a ligament or as a source of nutrition to the head and neck of the femur. The following statement from Jones and Lovett's 1929 edition of Orthopedic Surgery probably summarizes the current view: "The ligamentum teres is intra-articular, apparently concerned in strengthening the joint and 'probably vestigial

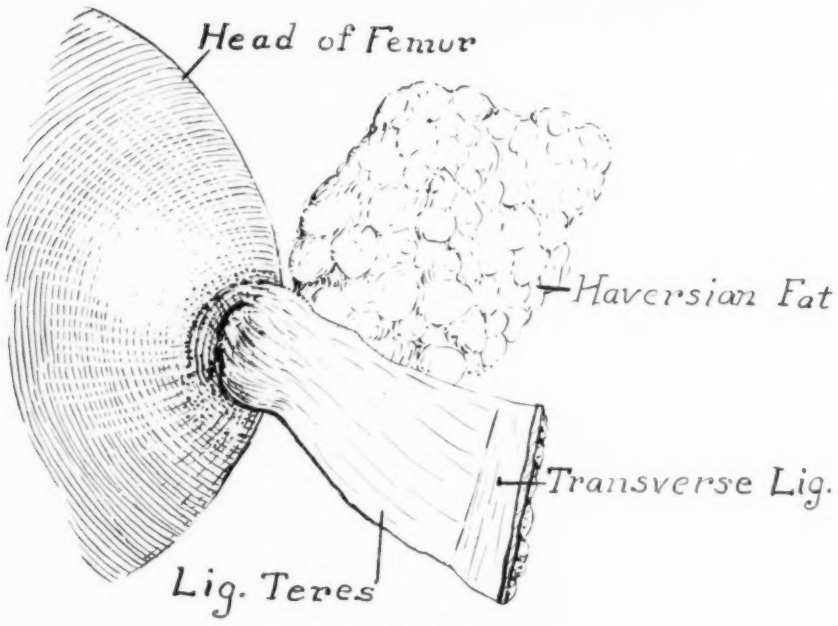

FIG. 1

A general view of the ligamentum teres. The haversian fat is attached to the dorsal surface of the ligament rather close to the head of the femur.

and practically useless'. It has been conclusively shown that the few vessels present in early life supply a small zone of articular cartilage only. In the adult the ligament is an avascular structure."

ANATOMICAL STUDY

The ligaments used in this study were removed from cadavera in the gross anatomy laboratory of Loyola University School of Medicine. The capsule of the hip joint was opened widely on the ventral, medial, and lateral aspects. The head of the femur was then slightly elevated from the joint so as to expose the ligamentum teres. The transverse ligament was then cut at both ends and the haversian fat removed from the non-articular portion of the acetabulum. The next procedure was to saw through the head of the femur and place all the tissue removed in ten per cent. formalin.

The gross appearance varied a great deal in different specimens. Excluding a few specimens in which gross pathology had taken place, and a few others where the embalming process had not been complete, all ligamenta teres removed appeared to be strong supporting structures. It is seldom round, but rather a flat band. The attachments are found to agree quite closely with that given in Cunningham's Text-Book of Anatomy. The distal attachment is into the superior one-half of the fovea capitis of the femur. The proximal insertion may be into the transverse ligament with some extensions into the lips of the acetabular notch. Records show

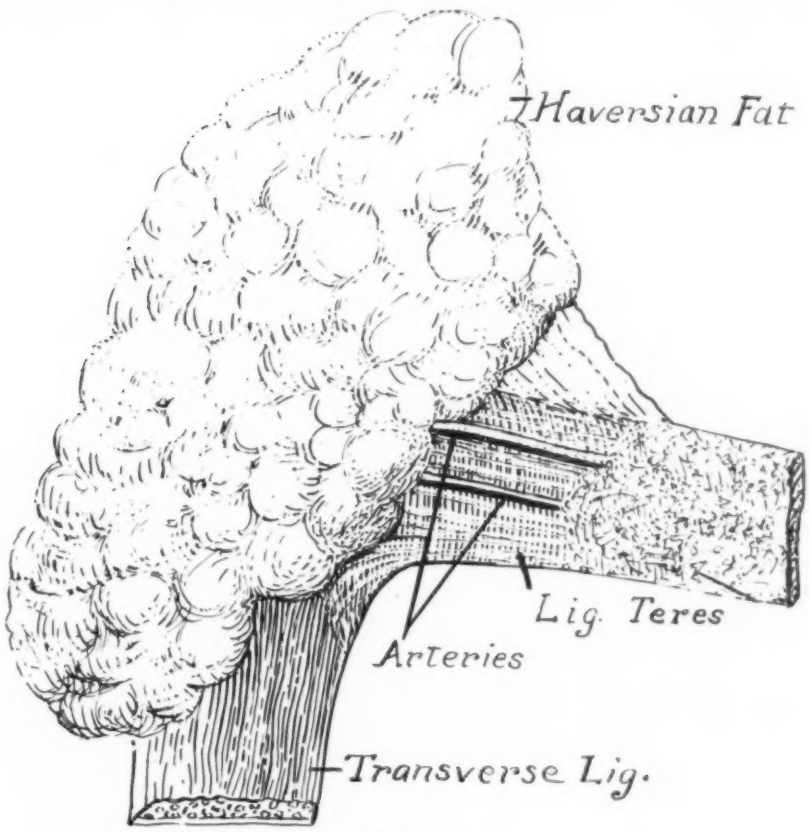

FIG. 2

A dorsal view of the transverse and teres ligaments, both partly covered by the haversian fat. Two macroscopic vessels pass to the femur along this surface of the round ligament.

that it is more commonly attached to the inferior lip and to a portion of the transverse ligament. The attachment may be into the inferior ischial lip of the notch alone.

All ligaments were removed from sixty-eight adult cadavera, the average age at death being forty-eight years. Measurements were made after hardening in formalin for a few days. The length of the fixed ligament was about two and five-tenths centimeters long and one to one and five-tenths centimeters wide and almost invariably three to four millimeters thick. In some cases the haversian fat was attached to the dorsal surface of the whole of the ligament, so that some measurements are approximations. Even when the haversian fat was attached more proximally, fat might extend all along the dorsal surface down to the fovea capitis. In one case the ligament did not appear to be anything but a fold of synovial membrane passing from the haversian fat to the fovea capitis. A macroscopic vessel was present, however. When sectioned, this structure was composed of ligamentous tissue (Figs. 3 and 4).

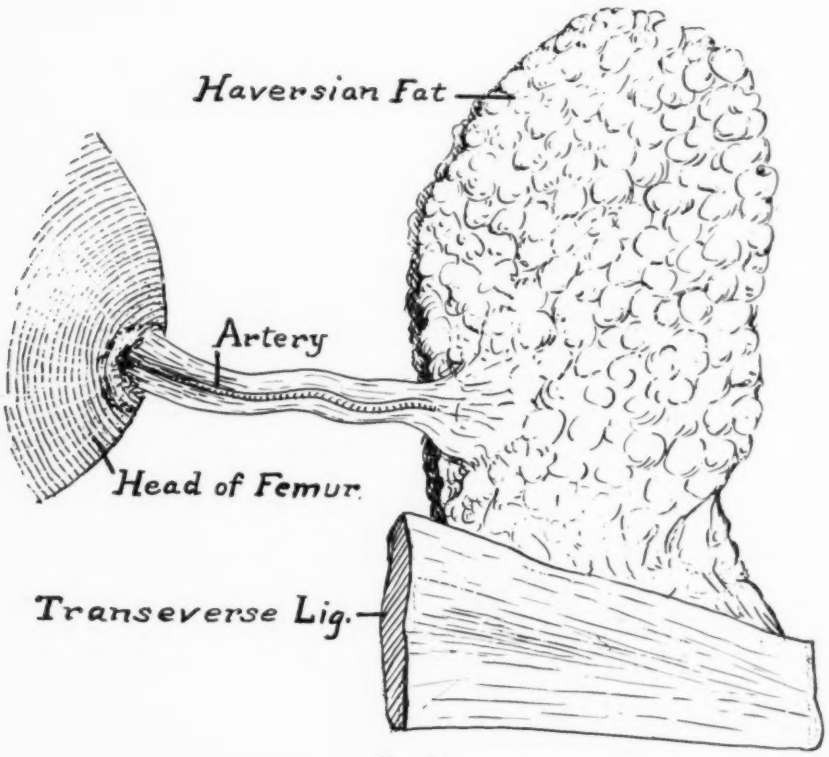

FIG. 3

The only atrophic ligament encountered. A macroscopic vessel passes from the haversian fat into the femoral head.

The histological preparations were made near the junction of the ligament with the femur. *All ligaments contained vessels,* but there was considerable variation in the number of vessels found. The observations support and extend those made by von Luschka and Langer.

The following table shows the size of the vessels and the number of ligaments in each group:

VASCULARITY OF 114 LIGAMENTA TERES IN MAN

Number of Ligaments	*Size of Vessels*
4	Relatively avascular
8	Many small vessels
16	Sclerosed, partially or wholly obliterating lumen
36	.2 to .4 m.m. in diameter
50	.4 to 1.5 m.m. in diameter

All measurements were made by the aid of an ocular micrometer and camera lucida drawings. The distribution of the vessels is not at all constant. Vessels may be on the dorsal surface or near the center of the ligament. They may be surrounded by loose areolar connective tissue and fat, or found coursing between heavy bundles of ligamentous tissue.

CLINICAL DISCUSSION

Observations were made on three fractures in cadavera. In all three instances the fracture had been complete, so that the only nourishment to the proximal fragment was through the ligamentum teres. In the first case, the gross and microscopic appearance was greatly distorted by a very extensive inflammation. Many newly formed vessels were present. In the second case, the fracture had existed about three months. The fragments were in apposition and held together by loose adhesions. The ligamentum teres contained a macroscopic-sized vessel and some injected material. In the third case, the patient lived about three years after the fracture. The largest vessel in this ligament was about one and five-tenths millimeters in diameter. A fibrous union had taken place. Serial sections of the ligament and the head of the femur showed that the vessel divided into smaller branches as soon as it penetrated the substance of the bone (Fig. 11).

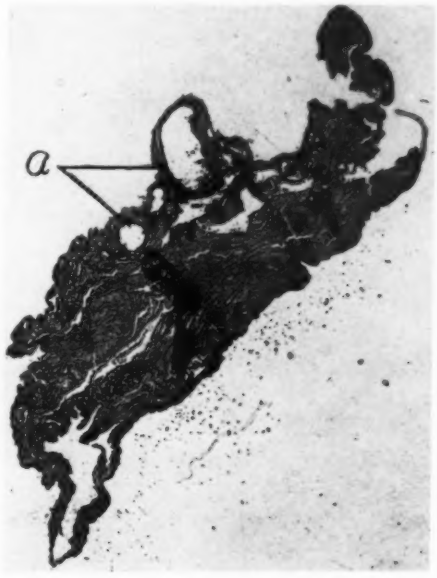

FIG. 4

A photomicrograph of the ligament shown in Fig 3. Bundles of ligamentous tissue are present. Several fair-sized vessels (*a*) shown peripherally. (×9.)

FIG. 5

The ligamentum teres and the vessels contained therein. The largest vessel (*a*) is 1.3 m.m. as measured on the slide. A smaller independent vessel is shown (*b*). (×9.)

Schmorl (1924) reports a similar case of complete fracture of the neck, including the vessels in the synovial membrane, but union occurred because of the blood supply through the ligamentum teres.

A more detailed histological study was made from serial sections of the ligaments and a portion of the head of the femur in six specimens, including two of the fracture cases (Figs. 8, 9, 10, 11). These all show con-

FIG. 6

Cross-section view of the ligamentum teres, showing a vessel surrounded by an area of fat and loose areolar connective tissue (*a*), also numerous smaller vessels.

FIG. 7

A relatively avascular ligamentum teres. Only precapillary vessels were observed in this specimen. (×9.)

clusively that the vessels of the ligament divide in the substance of the head of the femur to nourish the bone.

The information gained from this anatomical and histological study has a very definite clinical application. From the careful examination of 114 ligaments taken from adult human cadavera, ranging in ages at death from twenty-five to seventy-five years, it is shown that in many instances there are vessels varying from very small arteries to those measuring one and five-tenths millimeters in diameter. The larger vessels were found in the older, as well as in the younger, cases. This was true also of those in which there were a number of vessels. Those vessels showing sclerosis were practically all in older subjects. It is assumed that in these cases there was present a generalized arteriosclerosis. It was, furthermore, shown from the serial sections that vessels penetrated the head of the femur in cases of varying ages.

In operations for congenital dislocations of the hip in the young, it has been observed that in some cases, at least, there were only small macroscopic vessels in the small stretched-out ligaments in those cases where the x-ray films show infantile femoral heads. Fairly large vessels were found in the ligaments in some cases where the head, even though out

of the acetabulum, was of fair size and shape. None of these ligaments were, for obvious reasons, submitted to cross section and study.

It is not our conclusion from this study and from clinical observation that the entire proximal portion of the femoral head is dependent upon the blood supply coming through the ligamentum teres. We believe with Schmorl that, when the vessels and periosteum surrounding the neck of the femur are completely torn or loosened, non-union of the head to the neck often occurs. It is entirely possible, however, that in severe injury to the head and neck, as occurs in fractures and dislocations, the vessels in the ligament may, by direct tear or torsion, have been obliterated.

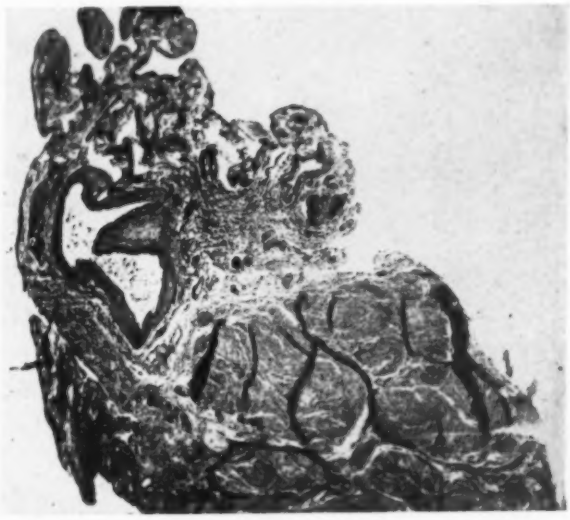

FIG. 8

The ligamentum teres from Case 3 of the fracture series. Very large artery shown partially collapsed.

We believe that the arterial supply through the ligament is of so much importance that great care should be exercised in all hip operations. A large hole drilled through the head of the femur may easily extend into the fovea and destroy the ligamentous attachment, as occurred in one of our cases. The operation was done ten months after the fracture; the head seemed normal as to circulation; the capsular attachment

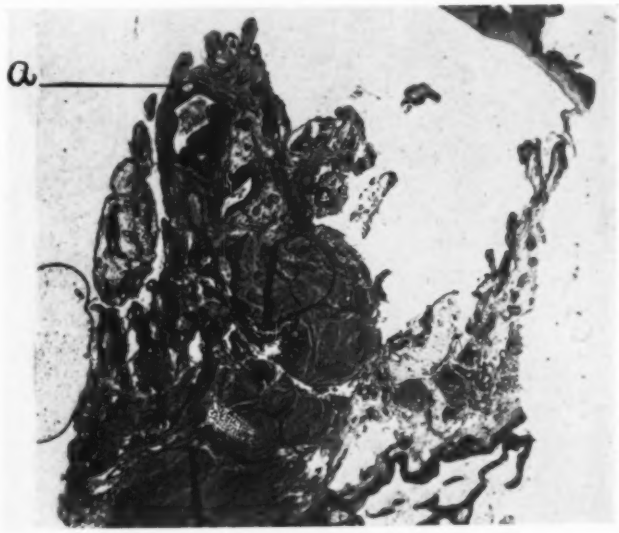

FIG. 9

Same as Fig. 8 except at the junction of the ligament with the fovea capitis. The small artery (*a*) is a branch of the larger one.

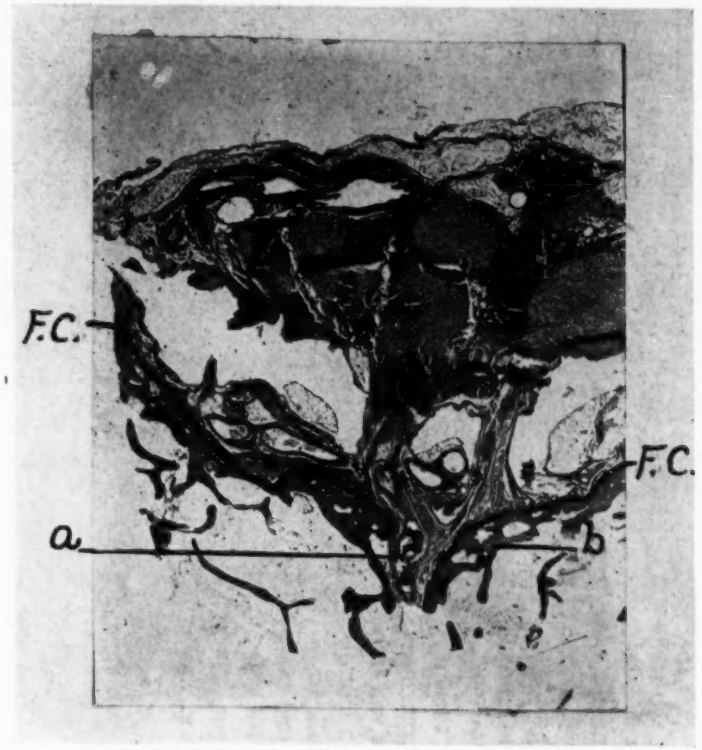

FIG. 10

One of the serial sections through the fovea capitis. Artery marked *a* is passing between the bone trabeculae (*b*) into the head of the femur. Outline of fovea capitis (*F.C.*) is indicated by heavy line.

FIG. 11

Three sections beyond that shown in Fig. 10. The artery in Fig. 10 has now divided into two branches (*a*) in the head of the femur. Fovea capitis indicated by heavy line (*F.C.*).

FIG. 12

Mrs. R., December 17, 1928. Non-union shown ten months after fracture.

FIG. 13

Mrs. R., April 9, 1930. Union of fracture thirteen months after bone graft. Bone graft extends directly into fovea. Very little weight-bearing had been permitted to this time.

FIG. 14

Mrs. R., May 1, 1932. Same case as shown in Figs. 12 and 13, thirty-seven months after operation. Blood supply from ligamentum teres having been destroyed by large bone drill opening into fovea, the head has collapsed and has assumed a triangular shape with apex of triangle at fovea.

FIG. 15

Central dislocation without fragmentation of head of femur. No fracture of the neck was observed.

FIG. 16

Necrosis six months after accident, such as seen in Perthes' disease, is confined to that area immediately surrounding the fovea. Note penetration of process toward neck, only slightly laterally.

FIG. 17

Ten years after accident. Greatest destruction has taken place in central cone of head.

and the vessels about the neck were not disturbed. Several months after operation some atrophy was observed in the head. Marked absorption is now shown three years after the bone-graft operation (Figs. 12, 13, 14).

Traumatic dislocation of the hip often completely severs the ligament and cases have been reported where flattening of the head occurs. A girl, aged fourteen, sustained a central dislocation of the femoral head (Fig. 15). Immediate replacement of the head was done by the closed method. There was no fragmentation of the head nor was there a fracture of the neck. Six months later the patient returned to the hospital because of slight pain in the hip with some muscular fixation. The x-ray film showed a definite necrosis in the region of the fovea (Fig. 16). The appearance was not unlike that of Perthes' disease, except that the aseptic necrosis was confined so definitely to the region where the ligament attaches. The process of necrosis seemed to extend from the fovea directly into the head and only slightly laterally. Films made at frequent intervals showed that the destruction had ceased after invading that portion which we have reason to believe is supplied by the arteries of the ligament, as shown in the most recent examination, ten years after the accident (Fig. 17). This might well be diagnosed as a destruction of the ligament, Perthes' type, with an absence of blood supply of the ligamentum teres as the etiological factor. There is, however, in this case more marked limitation of motion at the hip than we usually find. Flexion is limited to a right angle; extension is almost entirely absent; and rotation is limited to several degrees, showing that the entire head has undergone a change in size and conformation. In all operative procedures upon the hip, a careful manipulation of the head of the femur is imperative. Most careful handling, according to the method of Smith-Petersen, or some similar method, is to be recommended.

We should hesitate to remove the head from the acetabulum for the purpose of pegging it to the neck with beef bone or steel screw as reported in some recent articles [3, 4].

SUMMARY

Observation on 114 ligamenta teres of the hip joint in man justify the following conclusions:

1. A true ligament was present in every instance except one.

2. All ligaments contained vessels. In four cases the vessels were of precapillary size. All other ligaments contained a significant blood supply.

3. Serial sections of the junction of the ligament with the femur demonstrate an anastomosis between the vessels in the ligament and those of the head of the femur.

4. This anatomical study supplemented by clinical experience strongly supports the conviction that the ligamentum teres and its circulation should not be disturbed in any operative procedure.

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A SURVEY OF THE TREATMENT OF TUBERCULOSIS OF THE KNEE JOINT

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In this article an attempt will be made to put forward a rational method of treating cases of tuberculosis of the knee joint. Despite the large amount of work that has been and is being done on the subject, a study of the literature shows that no unanimity has been reached in connection with the important problems involved in such treatment; and it will be for this reason my secondary aim to suggest a possible explanation for the prevailing disharmony of opinion.

The following quotations from the works of recognized authorities show sufficiently how little agreement has so far been attained on this subject:

"In childhood, under favorable conditions, ultimate recovery, with fair functional use of the joint, may be anticipated; while a radical operation, although it may cure the patient in a shorter time, takes away the possibility of a cure with motion. . . . in childhood, the removal of portions of the epiphyses and of the epiphyseal cartilages entails a progressive inequality in the limbs, due to loss of growth; furthermore, unless the limb is protected by mechanical means, deformity is the rule, even though the disease has been thoroughly removed."[1]

Results obtained by medical treatment only at the New York Orthopaedic Hospital, as reported by Dr. Whitman, showed:

Thirty-seven per cent. with movement at the knee from 180 degrees to 90 degrees.

Thirty-four per cent. with movement from 180 degrees to between 90 degrees and 165 degrees.

Twelve per cent. with ankylosis in extension.

Twelve per cent. with ankylosis in flexion.

Five per cent. with flexion deformity without ankylosis.[2]

Results obtained by arthrodesis at two different clinics, as quoted by Dr. Whitman, were:

Twenty-seven per cent. with the knee fixed in extension.

Twenty-eight per cent. with the knee fixed in moderate flexion.

Forty-five per cent. with the knee fixed in marked flexion.[3]

and:

Ninety-one per cent. with the knee fixed in extension.

Nine per cent. with the knee fixed with deformity.[4]

Fraser calls attention to the fact that "the infection is more frequently in the synovial membrane than in the bone". He states: "If the case comes under appropriate care sufficiently early, one can usually guarantee a complete cure. In certain of these cases the movement

of the joint will be perfect in every respect; in the majority, while there is healing of the actual disease, the movements may be limited through varying degrees . . . in young children, if there is a likelihood of operation becoming necessary, such ought not to be delayed too long."[5]

"The philosopher would look upon it as a dispensation of providence that it is in the knee joint, where our conservative treatment most frequently suffers shipwreck, that operative treatment has achieved its most brilliant results."[6]

"Tuberculosis of the knee joint becomes manifest in the majority of cases only as a synovitis. . . . Generally speaking the tendency to recover is greater in bone lesions than in tuberculous synovitis."[7]

The site of primary incidence, as discovered by opening the knee joint, is shown by two different clinics to be:

Ninety-three per cent. in the synovial membrane.
Seven per cent. in the bones about the joint.[8]

and:

Forty-nine per cent. in the synovial membrane.
Fifty-one per cent. in the bones about the joint.[9]

The site of primary incidence shown by dissecting adult amputation stumps was:

Forty-one per cent. in the synovial membrane.
Fifty-nine per cent. in the bones about the joint.[10]

Such a diversity of opinions on the factors governing prognosis and treatment seemed to me to justify a fresh investigation. It was decided, accordingly, to follow up the cases treated by the orthopaedic department of Saint Thomas's Hospital and at the orthopaedic hospitals for children at Pyrford. The series consisted, then, of all the cases treated between the years 1920 and 1930 of which records were available.

To eliminate any confusion that might arise from possible errors in diagnosis, it was decided to consider separately those cases in which absolute proof of tuberculosis was obtainable and those in which the diagnosis was not beyond dispute. Two proofs only were accepted as conclusive evidence of tuberculous infection: either a record that the typical microscopic appearance of tuberculosis was seen, or that tubercle bacilli had been demonstrated in the caseous material from the joint or the cavity in the bone. My method of deciding whether the primary lesion was in bone or synovial membrane was simple but perhaps open to criticism. In all those cases in which the skiagram showed local (as opposed to general) rarefaction of bone the presence of a primary osseous focus was assumed, while in the others the primary focus was assumed to be in the synovial membrane. The great difference in prognosis in the two groups, as shown by the data to be presented in this article, affords ample justification for this way of distinguishing between them; moreover, it seems the only method available in those cases in which the interior of the joint has not been inspected.

ANALYSIS OF CASES CONSTITUTING THE SERIES

The series under discussion includes seventy-eight cases treated between the years 1920 and 1930. In the following analysis each will be given its serial number as it appears in the total group, and it should be realized that many of the cases are referred to under more than one heading, illustrating, as they do, different points that it was desired to bring out.

In the following sixteen cases the presence of tuberculous disease was confirmed by applying the criteria previously mentioned,—namely, either there was microscopic evidence of tuberculosis in a piece of excised synovial membrane or tubercle bacilli were demonstrated in pus from the joint.

SYNOVIAL TUBERCULOSIS

Proven Cases

Case 13. Immobilized for 5 years; arthrodesis; bony union in ¾ year.
Case 14. Immobilized for 3¼ years; result, still active; still in a caliper.
Case 18. Immobilized for 2¼ years; result, walking without caliper, range 30 degrees.
Case 29. Immobilized for 2½ years; arthrodesis; still in plaster 1 year later.
Case 30. Immobilized for ½ year; arthrodesis; bony union in 1¾ years.
Case 36. Immobilized for 2 years; result, still in a caliper.
Case 39. Immobilized for 3 years; result, range 5 degrees.
Case 40. Immobilized for ¾ year; result, range 175 degrees to 100 degrees and increasing.
Case 54. Immobilized for 2 years; arthrodesis; bony union progressing well ½ year later.
Case 56 Immediate arthrodesis; result, still in a splint 1½ years later.
Case 60. Immediate arthrodesis; result, bony union in 2¼ years.
Case 66. Immediate arthrodesis; result, bony union in 1 year.
Case 67. Immediate arthrodesis; result, bony union in ¾ year.
Case 68. Immediate arthrodesis; result, bony union in 1 year.
Case 69. Immediate arthrodesis; amputated 4 months later because of sepsis.
Case 74. Immediate arthrodesis; result, bony union in 1 year.

Unproven Cases

The group diagnosed clinically as synovial tuberculosis, but not proved to have been so, has been divided for convenience into: (a) those which were treated by immobilization only; (b) those in which immobilization was followed by arthrodesis; (c) those which were treated by arthrodesis without previous immobilization.

(*a*). *Treated by immobilization only*

Case 2. Immobilized for 2¾ years; result, still in a caliper.
Case 3. Immobilized for 10 years; result, full range.
Case 5. Immobilized for 2¾ years; result, slight limitation of flexion.
Case 6. Immobilized for 4½ years; result, unsound ankylosis in extension.
Case 7. Immobilized for 6 years; result, range 175 degrees to 150 degrees.
Case 9. Immobilized for 3½ years; result, still in a caliper, range 165 degrees to 160 degrees.

Case 10. Immobilized for 3½ years; result, range 180 degrees to 175 degrees.
Case 11. Immobilized for 5 years; result, range 175 degrees to 120 degrees.
Case 16. Immobilized for 3¾ years; result, range 175 degrees to 90 degrees.
Case 17. Immobilized for 6½ years; result, not known.
Case 19. Immobilized for 3½ years; result, full range.
Case 21. Immobilized for 6¼ years; result, fixed in extension, still in a caliper.
Case 24. Immobilized for 4½ years; result, fixed in extension.
Case 26. Immobilized for 1 year; result, still in a caliper.
Case 27. Immobilized for 1½ years; result, full range.
Case 31. Immobilized for 13 years; result, unsound ankylosis, flexing in caliper.
Case 32. Immobilized for 1 year; result, range 180 degrees to 170 degrees. Died 3 months later of tuberculous meningitis.
Case 33. Immobilized for 3 years; result, still in a caliper.
Case 41. Immobilized for 7 years; result, still in a caliper.
Case 42. Immobilized for 2¾ years; result, range 180 degrees to 90 degrees.
Case 43. Immobilized for 6 years; result, unsound ankylosis in 30 degrees' flexion.
Case 44. Immobilized for 7 years; result, fixed in extension.
Case 46. Immobilized for 14¼ years; result, fixed in extension.
Case 48. Immobilized for 5½ years; result, range 190 degrees to 60 degrees.
Case 51. Immobilized for ¾ year; result, full range.
Case 57. Immobilized for 3 years; just begun to get up in caliper.
Case 70. Immobilized for 3 years; result, full range.
Case 71. Immobilized for 2 years; result, full range.
Case 73. Immobilized for 2 years; result, full range.

(*b*). *Treated by immobilization followed by arthrodesis*

Case 1. Immobilized for 7 years; bony union in 1½ years.
Case 4. Immobilized for 6¾ years; bony union in 1 year.
Case 15. Immobilized for 4 years; bony union in 1 year.
Case 37. Immobilized for 2½ years; bony union in 3½ years.
Case 38. Immobilized for 5¼ years; bony union in 5½ years.
Case 50. Immobilized for 1½ years; bony union in ½ year.
Case 59. Immobilized for 7 years; bony union in 1¼ years.
Case 61. Immobilized for 2¾ years; bony union in ½ year.
Case 65. Immobilized for 1¼ years; bony union in 2¾ years.
Case 77. Immobilized for 4 years; bony union in ½ year.

(*c*). *Treated by arthrodesis without preliminary immobilization*

Case 20. Arthrodesis; result unknown.
Case 52. Arthrodesis; died a month later of tuberculous bronchopneumonia.
Case 53. Arthrodesis; bony union in ½ year.
Case 55. Two arthrodeses; bony union in 10 years from the date of the second operation.
Case 58. Arthrodesis; bony union in 3 years.
Case 63. Arthrodesis; result unknown.
Case 64. Arthrodesis; bony union in ½ year.
Case 72. Arthrodesis; bony union in 1¼ years.

OSSEOUS TUBERCULOSIS

Proven Cases

In the following five cases the presence of tuberculosis was confined by applying the criteria already set forth:

Case 8. Immobilized for 2¾ years; two sequestrectomies during that time; result, range 175 degrees to 45 degrees.

Case 22. Immobilized for 3 years; two sequestrectomies during that time; result, full range.

Case 45. Immobilized for 4¾ years; abscess opened during that time; result, fixed in extension.

Case 62. Immobilized for 2 years; result, full range. Died later of tuberculous meningitis.

Case 76. Immobilized for ½ year; abscess opened; result, still in a caliper.

Unproven Cases

In the following five cases the clinical condition of the joint suggested tuberculous disease, but the diagnosis was not confirmed. That the diagnosis was none the less correct is suggested by the fact that two patients in this group died of tuberculous meningitis.

Case 23. Immobilized for 2 years; result, fixed in extension. Died later of tuberculous meningitis.

Case 28. Immobilized for 2½ years; result, range 180 degrees to 130 degrees.

Case 34. Immobilized for 2 years; result, full range.

Case 35. Immobilized for 4 years; result unknown.

Case 47. Immobilized for 4 years; result, fixed in extension. Died later of tuberculous meningitis.

NON-TUBERCULOUS CASES

This group, to which I wish to draw special attention, includes those cases in which, despite a clinical diagnosis of tuberculosis and observation for varying lengths of time, synovectomy followed by microscopic examination showed no evidence that such disease had in fact been present.

In the series of seventy-eight cases, diagnostic synovectomy was carried out twenty-six times and on five occasions suggested that the diagnosis was wrong. The results of treatment in these five cases differ so markedly from those of the other cases in the series as to corroborate the absence of tuberculosis found at microscopy, which in each case disclosed a non-specific chronic inflammation of the synovial membrane. In view of the theory that in these non-tuberculous cases simulating tuberculosis the cause of the condition is an unsuspected syphilitic infection, it has been thought worth while to record the result of the Wassermann reaction in the two cases in which it was obtained.

Case 12. The knee joint of this patient, aged four years, was immobilized for eight months and then opened and drained on account of sepsis. Lack of improvement after three months necessitated amputation above the knee.

Case 25. The knee joint of this patient, aged eight years, was immobilized for four years and then a synovectomy showed the absence of tuberculosis. One year later the range of movement was 178 degrees to 45 degrees; the joint creaked. The Wassermann reaction was negative.

Case 49. Tuberculosis of the knee joint was diagnosed when this patient was five years old, and, after two years of immobilization, the knee was said to be normal. The patient came under observation again, at the age of twenty-one, with a history of recent

trauma to the joint. In view of the history and of the clinical signs, a diagnosis of tuberculosis was made. Arthrodesis was carried out at once but subsequent microscopy showed evidence of non-tuberculous infection only.

Case 75. In this patient, aged nine and three-quarters years, a clinical diagnosis of tuberculosis of the knee joint was made. The Wassermann reaction was negative. Synovectomy was carried out forthwith and no evidence of tuberculosis was found. Five months later the knee appeared normal.

Case 78. The knee joint of this patient, aged four and one-fourth years, was immobilized for two and one-half years following a diagnosis of tuberculosis. At the end of this time, the range of movement at the knee joint was 180 degrees to 60 degrees. In view of the fact that full range of movement was never attained, in spite of full use of the joint, synovectomy was carried out one and one-half years later: again evidence of non-tuberculous infection was found. Two-and-a-half years later the range of movement was 175 degrees to 95 degrees, and creaking was marked.

PROGNOSTIC SIGNIFICANCE OF PATIENT'S AGE

With a view to discovering what relation, if any, exists between the age of the patient when arthrodesis is carried out and the time taken to achieve bony union, the following analysis has been made, recording the age of the patient and the time taken to achieve bony union.

Case Number	Age at Arthrodesis (*Years*)	Time Taken to Achieve Bony Union (*Years*)	Case Number	Age at Arthrodesis (*Years*)	Time Taken to Achieve Bony Union (*Years*)
1	14	1½	56	19	1½+
4	13	1	58	58	3
13	10¾	¾	59	9¼	1¼
15	13¾	1	60	30	2¼
20	15	Result unknown	61	22	¾
29	14	1+	63	28	Result unknown
30	14¾	1¾	64	22½	½
37	15½	3½	65	11¼	2¾
38	6	5½	66	18¼	1
49	21	1½	67	21	¾
50	17	½	68	28	1
52	43	died	69	59	Amputation
53	28	½	72	39	1¼
54	16½	Result unknown	74	22	1¼
55	2	13	77	22	½

More shortly the above cases may be classified in the following age groups:

Age Group (*Years*)	Average Time Taken to Achieve Bony Union (*Years*)	Age Group (*Years*)	Average Time Taken to Achieve Bony Union (*Years*)
2 to 6	9¼	15 to 20	1½
9 to 12	1½	20 to 30	1
12 to 15	1¼	39 to 60	2

In only one patient under fifteen years of age,—namely, Case 55—was arthrodesis performed without previous immobilization.

Less than half the patients between fifteen and thirty years of age were treated by previous immobilization.

EFFECT ON BONY UNION OF PREVIOUS IMMOBILIZATION

With a view to discovering what relation, if any, irrespective of the age of the patient, exists between the duration of immobilization and the time taken after arthrodesis to achieve bony union, the following analysis was made:

Case Number	Duration of Immobilization (*Years*)	Time Taken to Achieve Bony Union (*Years*)	Age at Arthrodesis (*Years*)
1	7	1½	14
4	6¾	1	13
13	5	¾	10¾
15	4	1	15¾
29	2½	1+	14
30	½	1¾	14¾
37	2½	3½	15½
38	5¼	5½	6
50	1½	½	17
54	2	½+	16½
59	7	1¼	9¼
61	2¾	½	22
65	1¼	2¾	11¼
77	4	½	22

The lack of any discernible correlation between the length of treatment by immobilization and the time taken to achieve bony union seems to corroborate the finding of the previous analysis,—*i. e.*, that the time taken to effect bony union can be correlated most usefully with the ages of the patients.

SUMMARY OF CASES DIAGNOSED AS HAVING A SYNOVIAL INFECTION

Of seventy-eight cases, sixty-eight were diagnosed as primary synovial infections, and in sixteen of these the diagnosis was proved.

Proven Cases

Cases treated by immobilization only

The following results were obtained after an average period of immobilization of two and one-half years: of nine patients, four had unstable ankyloses (and were subjected to arthrodesis); two were still in a caliper; one had 5 degrees', one 30 degrees', and one 75 degrees' range of movement.

Cases treated by immobilization followed by arthrodesis

The average age in this group of four patients was fourteen years. Arthrodesis was performed after an average period of immobilization of

two and one-half years. In all these, bony union without deformity was attained in an average period of one and one-fourth years.

Cases treated by arthrodesis only

The average age in this group of seven patients was twenty-three years. In six of these, bony union followed arthrodesis in an average period of one and one-fourth years. In one patient, aged fifty-nine, sepsis necessitated amputation of the leg four months after the arthrodesis.

Summary of Findings in Proven Group

In no case was immobilization followed by complete return of the joint to its normal condition, or even by ability to bend the knee to a right angle. Arthrodesis was successful in obtaining bony union without deformity in every case except the one in which amputation became necessary. No patient died.

Unproven Cases

In the following fifty-two cases the diagnosis was not proved.

Treated by immobilization only

In this group of thirty-nine patients, the following results were recorded:

In three, sound ankylosis was attained after an average period of eight and three-fourths years.

In two, an unsound ankylosis was attained after an average period of nine and one-half years.

In ten, an unsound ankylosis was also attained, but, after an average period of immobilization of four and one-fourth years, arthrodesis was performed.

In one, slight movement remained with marked flexion deformity.

In three, the range of movement attained was between 30 degrees and 60 degrees.

In two, the range of movement attained was from 180 degrees to 90 degrees.

In nine, calipers were still worn at the end of an average period of four and three-fourths years.

In one, death from tuberculous meningitis occurred one and one-fourth years after the beginning of treatment.

In eight, a full range of movement was attained after an average period of immobilization of three and one-fourth years.

Treated by immobilization followed by arthrodesis

In this group of ten patients, treatment by immobilization was persisted in for four and one-fourth years. Arthrodesis, performed at an average age of fourteen and one-fourth years, was followed by bony union in an average period of one and three-fourths years.

Cases treated by arthrodesis only

In this group of eight patients, the average age was twenty-eight years. In two cases the result was unknown, and one proved fatal, the patient dying from tuberculous bronchopneumonia; in the remaining five, bony union occurred in an average period of two and one-half years.

Summary of Findings in Unproven Group

In eight patients out of thirty-nine, immobilization was followed by complete recovery of the joint. Arthrodesis was successful in obtaining bony union without deformity in all except the one who died. One other patient died.

SUMMARY OF CASES DIAGNOSED AS HAVING AN OSSEOUS INFECTION

In this group, consisting of only ten of the seventy-eight cases constituting the series, the results are as recorded below. The average age of the patients was six and one-half years.

Treated by immobilization only

Six patients were treated for an average period of two and one-half years, with the following results:

In three, death occurred from tuberculous meningitis at an average age of six and one-fourth years, although in one the knee had recovered completely.
In one, full range was recovered.
In one, a fair range was obtained.
In one, the result was unknown.

Treated by operation on the bony focus during immobilization

In four patients, treated for an average period of three and one-half years, the results were as follows:

In one, full range of movement was recovered.
In one, a good range was obtained.
In one, the knee was ultimately fixed in extension.
In one, the result was unknown.

By contrast with the "immobilization only" series, none of the patients in this group died.

Summary of Findings in Osseous Group

Half of the patients recovered a normal knee joint; half of those treated by immobilization only died; none of those treated by operation died. In none was arthrodesis necessary.

Although these cases are admittedly few in number, the results seem striking enough to justify tentative conclusions about the relative value of the different methods of treatment.

SUMMARY OF NON-TUBERCULOUS CASES

A diagnostic synovectomy was carried out in twenty-six cases, in five of which no evidence of tuberculosis was found. In two of the latter in which the Wassermann reaction was obtained, there was no evidence of syphilis. The average age in this group was six and one-half years and the average period of observation before synovectomy was two and one-fourth years.

In the five non-tuberculous patients, the following results were obtained:

In one, recovery was complete without treatment.

In one, recovery was complete after immobilization for two years.

In one, sepsis made amputation necessary.

In two, recovery was almost complete, leaving a condition similar to the osteo-arthritis of middle age.

CONCLUSIONS

1. Synovial tuberculosis was much commoner than osseous tuberculosis in the knee joint (in this series the proportion was sixty-eight to ten), and tended to occur at a later age.

2. In no proven case of synovial disease did the patient recover sufficiently to bend the knee to a right angle.

3. In no fewer than eight of forty-seven cases of unproven synovial disease was full range of the knee recovered.

4. Of twenty cases of synovial disease treated by immobilization for an average period of five years, in seventeen ankylosis was unsound enough to necessitate arthrodesis.

5. Arthrodesis produced bony union without deformity in all except two patients in whom it was undertaken; one of these died and the leg of the other had to be amputated. The average length of time for which immobilization was necessary after arthrodesis was one and one-fourth years in patients between the ages of nine and thirty. The arthrodeses were performed so as to fix the joint in full extension. Adequate protection of the limb was successful, even in children, in preventing subsequent deformity at the site of operation or at the epiphysis.

6. A careful examination of the skiagrams taken shortly after arthrodesis showed the epiphyseal lines (if present) to be intact in all cases. The distance of the epiphyseal cartilage from the end of the bone leaves the surgeon so much margin that such a result may reasonably be hoped for in synovial infection when the disease has not extended to the epiphyseal cartilage. Thus, following arthrodesis, there is no reason to expect shortening of the limb beyond that which is due to interference with growth by the tuberculous process.

7. The time taken to achieve bony union was independent of any variation in operative procedure. Furthermore, in patients of fifteen or over, it was unaffected by previous immobilization. In younger patients immobilization preceded arthrodesis in every case but one.

8. A comparison of the synovial and osseous groups with respect to mortality brings out the fact that, in the former group, two deaths occurred in sixty-eight cases; whereas, in the latter, three deaths occurred in ten cases.

9. In half the cases of osseous disease complete recovery resulted. It is probable, therefore, that, in cases in which the disease is not too advanced, the knee joint suffers only a so called sympathetic inflammation from which recovery may reasonably be expected whenever radical treatment can be directed to the focus in the bone without opening the knee joint itself. Moreover, only thus can the spread of tuberculous infection into the joint be prevented with any certainty.

10. In the cases proved to be non-tuberculous, the disease of the synovial membrane appeared either to recover completely, or to pass into a condition resembling the osteo-arthritis of middle age, or to get definitely worse with the development of sepsis.

These facts suggest the existence of a distinct disease of the synovial membrane of the knee joint, which lasts for years without affecting other joints. It is not syphilitic. It tends with treatment (or even without) in some cases to get completely well, in some to recover partly, with the development of a premature osteo-arthritis, and in some to become septic. In all these cases the synovial membrane showed the microscopic appearance of a non-specific chronic inflammation.

11. The fact that no proven case of synovial disease recovered suggests that the eight cases of unproven disease that did so may be regarded as: (a) wrongly diagnosed, or (b) primarily osseous cases in which the bony focus was too small to show on the skiagram.

Against the latter view is the fact that none of these cases proved fatal. And in favor of the former is the fact that, of twenty-six cases subjected to synovectomy, five showed no evidence of tuberculous infection. There is, therefore, nothing improbable in the hypothesis that there was an error of diagnosis in eight of the forty-two unproven cases.

RECOMMENDATIONS

1. Since it seems impossible, according to the data herein presented, to be sure of the diagnosis of tuberculosis of the knee joint, even in cases that have been observed for several years, it is suggested that diagnosis by synovectomy should be carried out on all patients over nine years of age (except in those in which the skiagram gives evidence of a bony focus) as soon as the diagnosis of a chronic arthritis is established. Under the age of nine, since treatment will be by immobilization in any event, a synovectomy is not indicated.

2. In view of the facts—that after immobilization for an average period of five years a clinically sound ankylosis resulted in only three of twenty cases in this series, that the evidence suggests that tuberculosis of the knee joint very seldom recovers, and that arthrodesis usually insures bony union in one to one and one-half years—it is further suggested that, in proven cases of tuberculosis of the knee joint, immediate arthrodesis should be carried out on patients aged fifteen years or over, except perhaps in the very earliest cases. Again, when skiagraphic evidence of destruction of cartilage is present, arthrodesis is indicated in patients over nine years of age.

3. Arthrodesis is to be condemned before the age of six, and it is probably best to continue immobilization until the age of nine. After the age of fifteen, previous immobilization appears not to hasten bony union.

4. In view of the high mortality from osseous disease when treated by immobilization only (three in ten in this series), it is recommended that operation should invariably be carried out on the bony focus. It may be recalled that, in the cases discussed in this article, operation on the osseous focus did not affect the likelihood of complete recovery of the joint itself, and, in addition, prevented its infection by extension of the tuberculous process in the bone.

I wish to express my gratitude to Mr. Bristow and Mr. G. Perkins, surgeons in charge of the orthopaedic department of Saint Thomas's Hospital and of the orthopaedic hospitals for children at Pyrford, for allowing me free access to the records of the cases at the hospitals mentioned.

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A NEW METHOD FOR ROENTGENOGRAPHIC EXAMINATION OF THE UPPER END OF THE FEMUR *†

BY CLAYTON R. JOHNSON, M.D., LOS ANGELES, CALIFORNIA

Perfect apposition of fragments is an essential factor in obtaining acceptable results in treatment of fractures of the upper end of the femur. With single, anteroposterior examination it is impossible, and with stereoroentgenograms in the anteroposterior position it is often difficult, or impossible, to determine when satisfactory reduction has been accomplished (Figs. 5 and 6). With this point in view we set about to devise a simple, practicable method whereby it would be possible to obtain a comparatively undistorted roentgenogram of the upper end of the femur in the lateral position.

THEORETICAL CONSIDERATION

The neck of the femur, *N* (Figs. 1-A and 2-A), when examined from the anterior position, joins the shaft at an angle of about fifty degrees. By directing the central x-rays perpendicular to a plane which bisects this angle, it is then possible to cast a shadow of *N*, undistorted as to length, on sensitized film *C*, lying parallel to the longitudinal plane of the femoral shaft.

The neck of the femur, N (Figs. 1-B and 2-B), when examined from a lateral position, slopes dorsally with relation to the torso about twenty-five degrees. By directing the central x-rays at an angle of twenty-five degrees below the horizontal plane through the femoral neck, and tilting the plane of film *C* at an angle of sixty-five degrees with the horizontal, a true lateral projection may be obtained without superimposing shadows of other bony structures.

TECHNIQUE FOR EXAMINATION

1. Construct from a heavy piece of cardboard an anglemeter in the form of a right-angle triangle, the angles of which are ninety degrees, sixty-five degrees, and twenty-five degrees (Figs. 1-A and 1-B).

2. Have the patient in a supine position.

3. Place the cassette, *C*, containing the sensitized film, parallel with the longitudinal plane of the shaft of the femur, inclining outward at an angle of sixty-five degrees with the horizontal plane. Determine this angle accurately with the anglemeter (Fig. 1-B). Center the cassette just above the upper margin of the greater trochanter.

4. Use target film distance of thirty-six to forty inches with small cone which casts not more than an eight-inch circle of light on the cassette.

* From the X-ray Department of the Los Angeles County General Hospital.

† Read before a special meeting of the Los Angeles and San Francisco Orthopaedic Clubs at the annual session of the California State Medical Association, May 2, 1932.

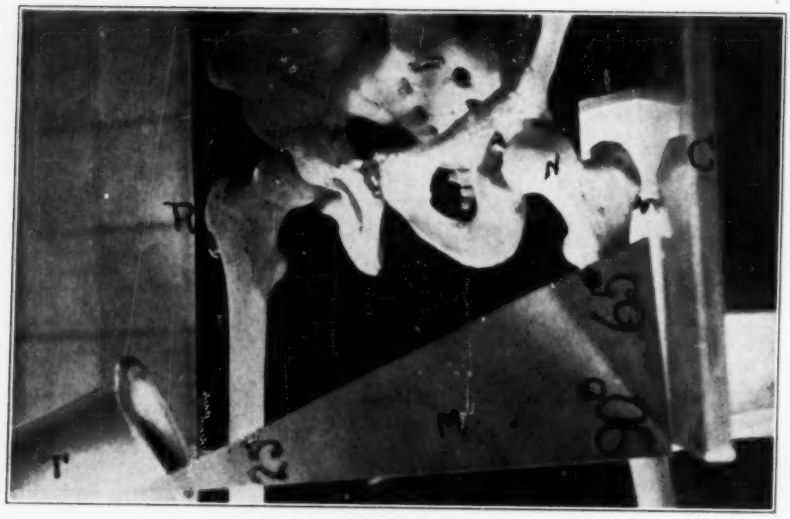

FIG. 1-A

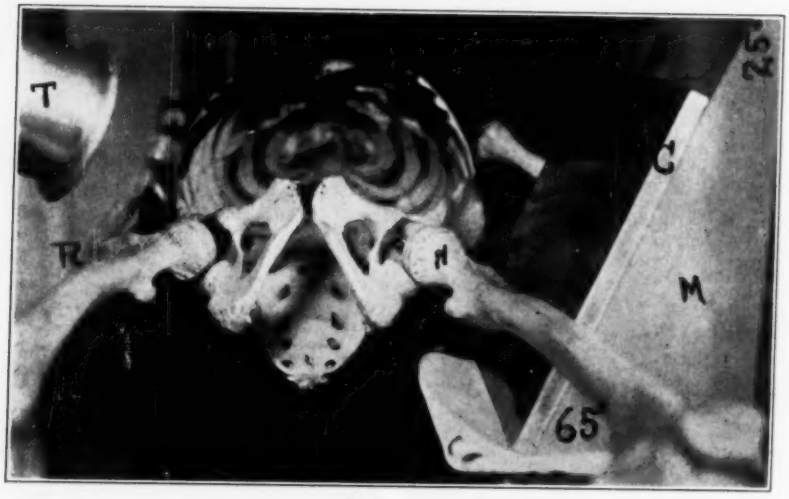

FIG. 1-B

Photographs of positions for examination as demonstrated with the skeleton. *T*, cone showing direction of central ray; *N*, neck of femur; *C*, cassette; *M*, anglemeter.

Place the base of the anglemeter (Fig. 1-A) parallel with the longitudinal plane of the shaft of the femur, the altitude in the transverse plane of the femoral shaft, and the hypotenuse on the upper side, its plane passing through the upper margin of the greater trochanter. Direct the central x-rays twenty-five degrees toward the table and in line with the hypotenuse of the anglemeter (Figs. 1-A, 1-B, 2-A, and 2-B).

If the thigh is in a position of abduction, follow the same general plan, always keeping the line of the central rays at an angle of twenty-five de-

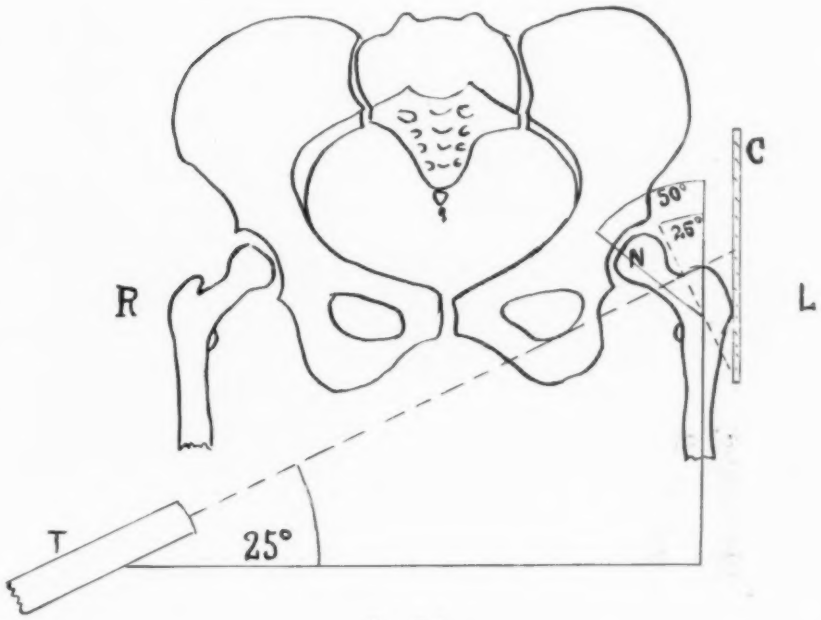

FIG. 2-A

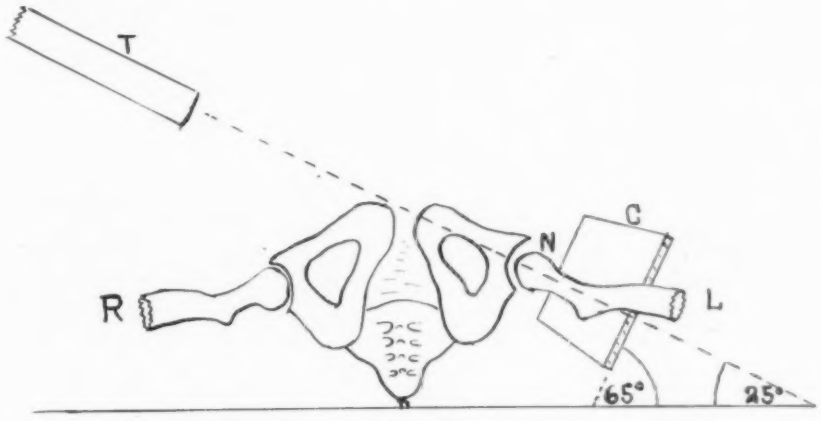

FIG. 2-B

Diagram showing angle of femoral neck, the proper direction of the central ray, and position of the cassette.

grees with the transverse plane of the femoral shaft. All angles must be accurate if distortion is to be prevented.

5. Use suitable exposure for the thickness of the part.

PRACTICABILITY

The examination above described may be accomplished at the patient's bedside or with the patient on the fracture table, with the average portable apparatus. The patient need suffer no discomfort whatsoever from the

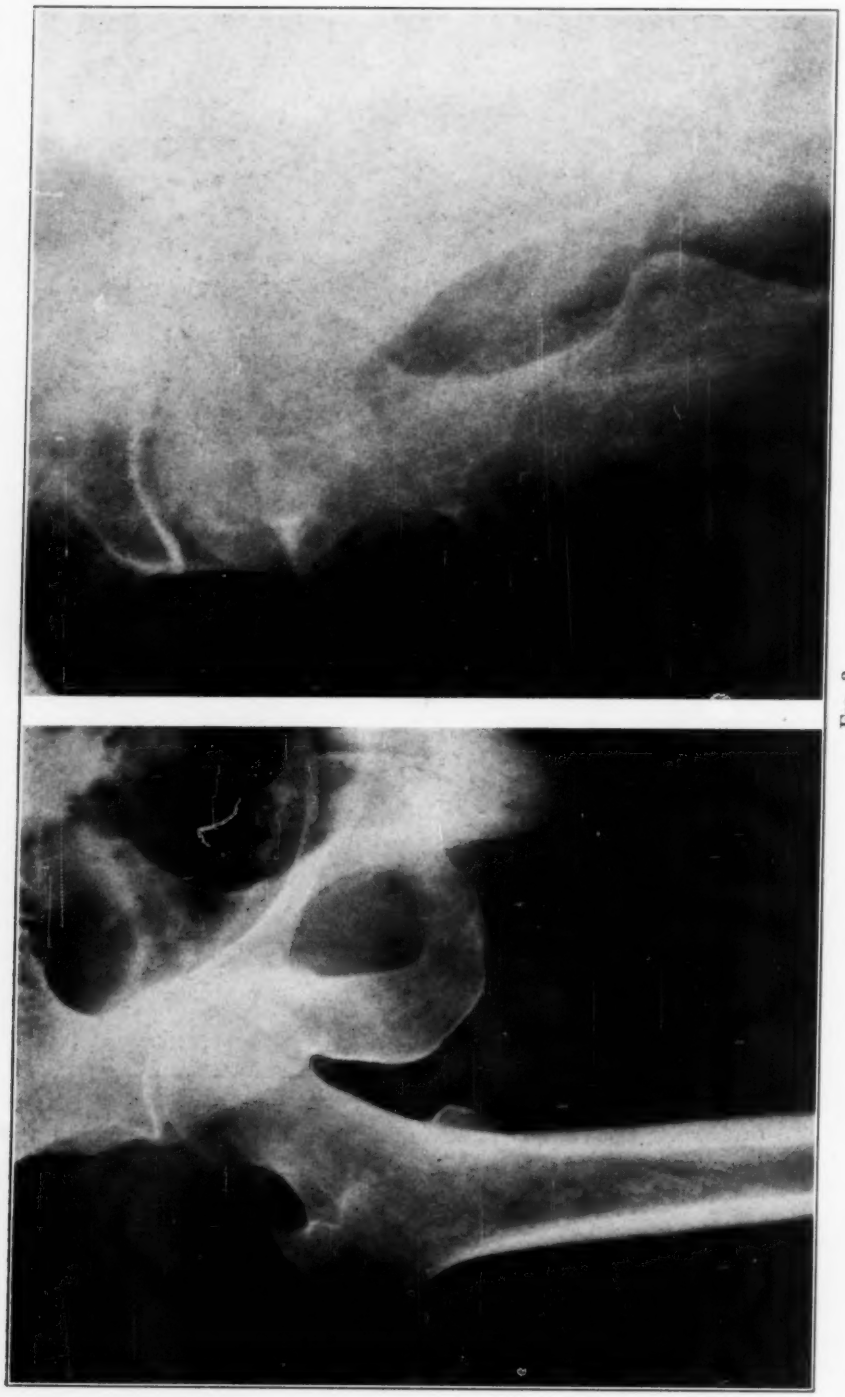

FIG. 3

Upper end of normal femur as shown on anteroposterior and lateral roentgenograms.

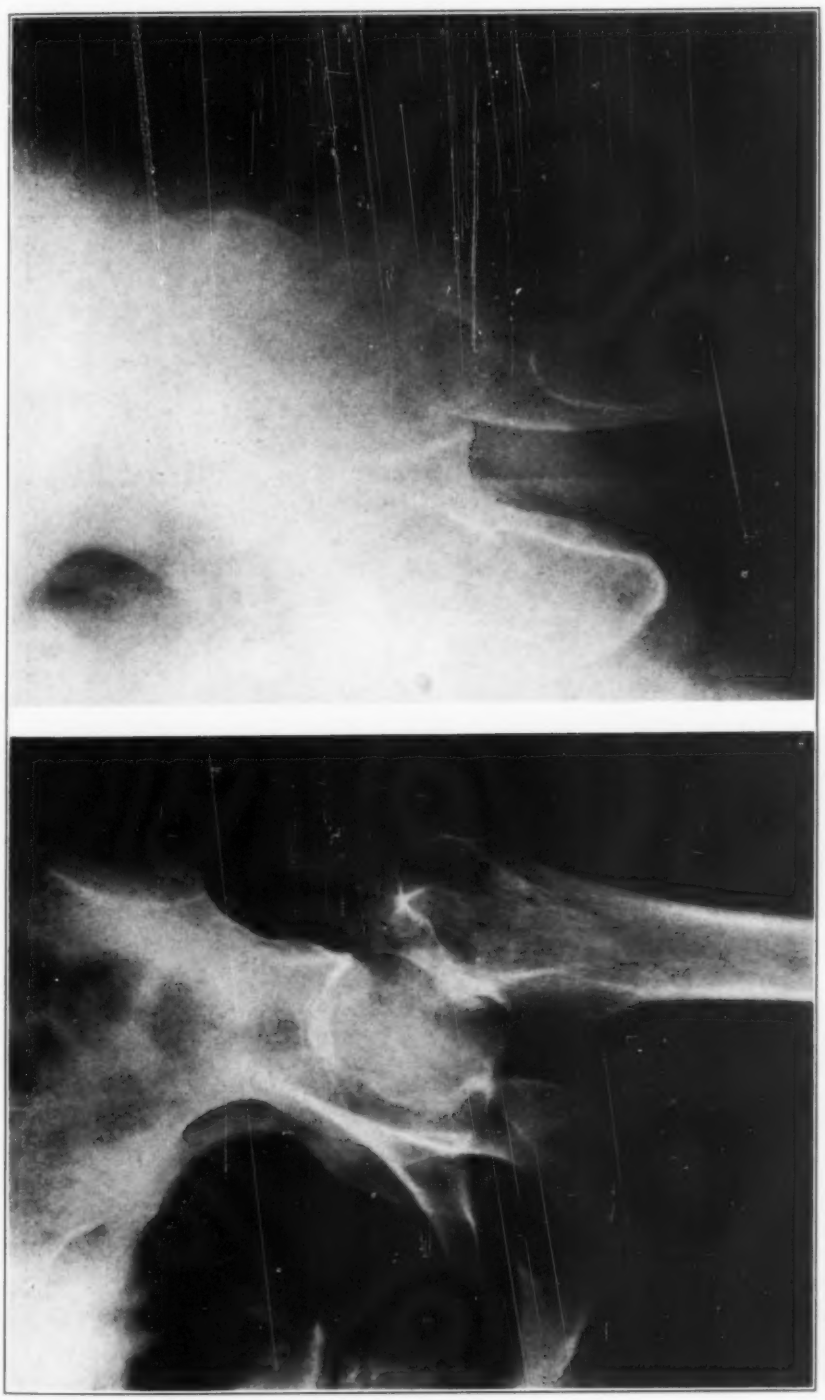

FIG. 4

Upper end of right femur showing usual deformity following fracture of the femoral neck.

FIG. 5

Same as Fig. 4, following attempted reduction. Anteroposterior view shows good apposition of fragments. Lateral view shows marked medial rotation of the head fragment.

FIG. 6

Following attempted reduction. Intertrochanteric fracture with anterior displacement of the shaft fragment, not detected on the usual anteroposterior roentgenogram.

procedure. The examination may be made entirely satisfactorily regardless of the type of immobilization which may be present.

SUMMARY

1. A method of roentgenographic examination of the upper end of the femur in the lateral position has been presented.

2. The method is particularly adapted to the study of fractures of the upper end of the femur.

3. It has been demonstrated that examination in the anteroposterior position is inadequate in detecting deformity which may be present following fracture and attempted reduction.

PARALYTIC DISLOCATION AT THE HIP IN POLIOMYELITIS *

BY EUGENE R. ELZINGA, M.D., FLINT, MICHIGAN, AND J. ALBERT KEY, M.D., ST. LOUIS, MISSOURI

In patients with extensive paralysis of the muscles of the pelvic girdle it is not unusual to find the paralyzed hip dislocated or to be able to dislocate the hip by flexion, adduction, and internal rotation. In our experience the dislocation has always been posterior and it has always been possible to reduce it with relative ease. As a rule, these patients are not ambulant and, as the hip is not painful, they do not know that it is dislocated nor that the head of the femur can be slipped in and out of its socket at will. However, when the surgeon fits the patient with braces and attempts to make him ambulant, the instability of the hip is found to be a serious handicap and major surgical operations are performed in efforts to make these hips more stable.

For a number of years one of us (J. A. K.) has been interested in these cases and has speculated as to what types of paralysis are apt to result in dislocation and as to whether or not a given type of paralysis will always result in dislocation. From time to time these speculations have taken the form of examining isolated cases of paralytic dislocation of the hip and comparing them with other cases, in which extensive paralysis of the hip was present, in an attempt to determine whether or not it would be possible to prognosticate dislocation in a given case.

The study of isolated cases led to the conclusion that dislocation was apt to occur in paralytic hips in which there were strong flexors and adductors and internal rotators with weak or absent extensors, abductors and external rotators. However from time to time cases were examined in which this combination had not resulted in dislocation and other cases were examined in which dislocation had occurred without this type of paralysis. As we were unable to find an analysis of paralytic dislocation of the hip in the literature, we decided to review all of the cases which had been seen in the St. Louis Unit of the Shriners' Hospital for Crippled Children and to compare these with a similar group of patients with extensive paralysis of the muscles of the hip in which dislocation had not occurred. It was hoped that this review might throw some light upon the mechanism of the condition.

Since the hospital opened in 1924 we have had twenty-five patients with paralytic dislocation of the hips. In one patient the dislocation was bilateral; consequently we have a series of twenty-six hips which have dislocated as a result of poliomyelitis. These occurred in 953 cases of

* From the Shriners' Hospital for Crippled Children, St. Louis, Missouri, and the Washington University Medical School, St. Louis, Missouri.

TABLE I

	Sex	Name	Side	Present Age (*Years*)	Age at Onset (*Years*)	Duration of Disease (*Years*)	Deformities at Hip	X-ray Appearance		
								Acetabulum	*Coxa Valga*	*Tilt Pelv*
Case 1	M	O.W.	L	14	1	13	Slight flexion	Poor	Severe	–
Case 2	F	L.H.	R	16	4	12	None			
Case 3	M	W.S.	R	6	2	4	External rotation	Good	Severe	0
Case 4	F	L.McD.	L	11	?	11	Slight flexion	Poor	Moderate	0
Case 5	M	C.H.	L	12	6 mo.	11	Moderate flexion	Poor	Severe	0
Case 6	M	B.T.	R	16	1	15	Moderate flexion	Fair	Severe	0
Case 7	F	P.D.	R	10	6 mo.	9	Severe flexion	Poor	Severe	+
Case 8	F	M.H.	R	16	1	15	Flexion	Poor	Severe	–
Case 9	F	B.B.	L	7	1	6	Flexion adduction	Poor	Severe	–
Case 10	F	Z.E.	R	18	1	17	40° flexion	Poor	Severe	0
Case 11	M	A.R.	R	16	4	12	Slight flexion	Poor	Severe	–
Case 12	F	R.R.	R	11	6	5	Moderate flexion			
Case 13	F	L.M.	R	11	9 mo.	10	30° flexion	Fair	Moderate	–
Case 14	F	F.R.	R	17	7	10	Moderate flexion	Poor	0	–
Case 15	M	B.R.	L	11	1	10	Slight flexion	Fair	Severe	0
Case 16	M	J.H.	L	9	2	7	None			
Case 17	F	W.B.	R	10	9 mo.	9	90° flexion	Poor	Severe	–
Case 18	M	R.H.	L	7	1	6	45° flexion	Poor	Moderate	+
Case 19	M	E.K.	R	10	1	9	Slight flexion	Poor	Severe	0
Case 20	M	G.B.	L	15	1	14	60° flexion	Poor	Severe	+
Case 21	F	M.B.	R	16	5	11	None	Fair	Moderate	–
Case 22	F	M.B.	L	16	5	11	35° flexion	Fair	Severe	+
Case 23	M	M.C.	R	11	3	8	30° flexion	Fair	Moderate	+
Case 24	M	K.A.	R	11	1	10	Moderate flexion	Good	Severe	+
Case 25	F	H.S.	R	12	4 mo.	12	45° flexion	Poor	Moderate	0
Case 26	M	J.T.	R	13	2	11	None	Poor	Severe	+

Table I. Clinical findings in twenty-six cases of paralyzed hips which dislocated. Muscles are listed as normal, good, fair, and zero. Acetabulum as good, fair, and poor. Coxa valga as severe, moderate, and zero. Tilted pelvis zero is normal, plus is varus favoring stability, and minus is valgus or tending toward dislocation.

TABLE II

	Sex	Name	Side	Present Age (*Years*)	Age at Onset (*Years*)	Duration of Disease (*Years*)	Deformities at Hip	X-ray Appearance		
								Acetabulum	*Coxa Valga*	*Tilt o Pelvi*
Case 1	M	G.E.	L	11	8 mo.	10	Slight flexion	Good	Moderate	0
Case 2	M	P.A.	L	14	3	11	Slight flexion			
Case 3	F	M.F.	L	14	5	9	None	Good	Severe	–
Case 4	F	Z.E.	L	18	1	17	None	Fair	Severe	0
Case 5	M	E.R.	L	8	1	7	None			
Case 6	M	E.K.	L	10	1	9	None	Good	Normal	0
Case 7	M	J.C.	R	10	1	9	None	Fair	Severe	–
Case 8	F	M.H.	L	16	1	15	Adduction	Good	Severe	+
Case 9	M	R.H.	L	12	9 mo.	11	None	Good	Severe	+
Case 10	M	B.B.	R	13	5 mo.	12	None	Good	Severe	+
Case 11	M	J.G.	R	14	3	11	60° flexion			
Case 12	M	H.C.	R	16	1	15	Moderate flexion	Good	Severe	+
Case 13	M	O.D.	R	9	7	2	None			
Case 14	F	E.C.	L	13	2	11	Slight flexion			
Case 15	M	A.R.	L	16	4	12	Flexion adduction	Good	Moderate	+
Case 16	M	B.R.	R	11	1	10	None	Good	Severe	0
Case 17	M	O.W.	R	14	1	13	None	Normal	Moderate	+
Case 18	F	M.T.	L	10	5	5	None	Good	Moderate	0

TABLE I—*Continued*

CONDITION OF MUSCLES

	Internal Rotators	*Flexors*	*Adductors*	*Abductors*	*Gluteus Maximus*	*External Rotators*	*Tensor Fasciae Latae*	*Quadriceps*	*Inner Hamstrings*	*Outer Hamstrings*
Case 1	Fair	Good	Good	0	Good	Normal	0	Good	Good	Good
Case 2	Good	Good	Fair	Fair	Good	Good	0	0	Good	Good
Case 3	Fair	Good	Normal	0	Good	Good	0	Good	Good	Fair
Case 4	0	Good	Fair	0	Good	Good	Fair	Good	Fair	0
Case 5	Fair	Good	Good	0	Good	Good	0	Good	Good	Good
Case 6	Good	Good	Normal	0	Good	Good	0	0	Fair	0
Case 7	Normal	Fair	Good	0	Fair	Good	0	Good	Good	Good
Case 8	Fair	Fair	Good	0	Fair	Good	0	Good	Fair	0
Case 9	0	Fair	Fair	0	Fair	Fair	0	Good	Good	Fair
Case 10	Fair	Fair	Good	0	Fair	0	Fair	0	Good	0
Case 11	Fair	0	0	0	Fair	Fair	0	0	Fair	Fair
Case 12	0	0	0	0	0	0	0	0	0	Good
Case 13	0	Good	0	0	0	0	0	0	Fair	0
Case 14	0	0	0	0	0	0	0	0	0	0
Case 15	0	0	0	0	0	0	0	0	0	0
Case 16	0	0	0	0	0	0	0	0	0	0
Case 17	0	0	0	0	0	0	0	0	0	0
Case 18	0	0	0	0	0	0	0	0	0	0
Case 19	0	Good	Normal	0	0	Good	0	Good	0	0
Case 20	Fair	0	Fair	0	0	0	0	0	0	0
Case 21	0	0	0	0	0	Fair	0	0	0	Good
Case 22	0	0	0	0	0	0	0	0	0	0
Case 23	Fair	Good	Fair	0	0	Good	0	Good	0	0
Case 24	0	Good	Fair	0	0	Fair	0	Fair	0	0
Case 25	0	0	0	0	0	Fair	0	0	0	0
Case 26	0	Normal	Normal	Fair	0	0	Fair	Normal	Good	0

TABLE II—*Continued*

CONDITION OF MUSCLES

	Internal Rotators	*Flexors*	*Adductors*	*Abductors*	*Gluteus Maximus*	*External Rotators*	*Tensor Fasciae Latae*	*Quadriceps*	*Inner Hamstrings*	*Outer Hamstrings*
Case 1	0	0	0	0	Normal	Good	0	0	Fair	Fair
Case 2	0	Fair	Fair	Fair	Normal	Good	0	Good	Good	0
Case 3	Good	Normal	Normal	0	Normal	Normal	0	Normal	Normal	Normal
Case 4	Fair	Fair	Fair	Fair	Normal	Good	Fair	0	Normal	Normal
Case 5	0	Normal	0	0	Normal	Good	0	Good	Good	Good
Case 6	Normal	Normal	Normal	Good	Normal	Normal	Fair	Normal	Normal	Normal
Case 7	Good	Normal	Good	0	Normal	Normal	0	Normal	Good	Good
Case 8	0	0	0	Fair	Normal	Good	0	Fair	Fair	Good
Case 9	0	0	0	0	Good	0	0	0	0	Fair
Case 10	0	Good	Fair	0	Good	Good	0	0	Fair	Fair
Case 11	Fair	Good	0	Good	Good	Good	0	0	Good	Good
Case 12	Good	Good	Good	Good	Good	Fair	Good	0	0	0
Case 13	Good	Good	Good	0	Good	Good	0	Good	Fair	0
Case 14	Fair	Good	Good	Good	Good	Good	Good	0	Fair	Good
Case 15	Fair	Fair	0	Good	Good	Good	Good	0	Good	Good
Case 16	Fair	0	0	0	Good	Good	0	0	0	Good
Case 17	Normal	0	0	Normal	Good	Normal	Normal	0	Good	Good
Case 18	Good	Good	Good	Fair	Good	Good	Fair	Fair	Fair	Fair

(*Continued on next page*)

TABLE II—*Continued*

	Sex	Name	Side	Present Age (*Years*)	Age at Onset (*Years*)	Duration of Disease (*Years*)	Deformities at Hip	X-ray Appearance		
								Acetabulum	*Coxa Valga*	*Tilt of Pelvis*
Case 19	F	J.J.	R	11	1	10	None	Good	Severe	0
Case 20	F	C.O.	R	5	1	4	None	Normal	Moderate	0
Case 21	F	M.M.	R	9	4	5	15° flexion			
Case 22	M	D.H.	L	13	5 mo.	12	None			
Case 23	M	B.P.	R	6	2	4	None			
Case 24	F	L.M.	L	11	9 mo.	10	Moderate flexion	Normal	0	+
Case 25	F	B.R.	L	10	6 mo.	9	Flexion	Good	Moderate	+
Case 26	F	R.C.	R	13	1	12	20° flexion	Good	Severe	−
Case 27	M	J.C.	L	10	1	9	None	Good	Moderate	+
Case 28	M	K.K.	R	7	2	5	Moderate flexion	Normal	0	0
Case 29	F	M.H.	R	11	1	10	None	Good	Moderate	0
Case 30	F	M.J.	L	8	3	5	None	Normal	Slight	−
Case 31	F	B.S.	R	10	3	7	None			
Case 32	F	W.Q.	L	9	5	4	None	Normal	0	0
Case 33	F	W.Q.	R	9	5	4	None	Normal	Moderate	0
Case 34	M	R.C.	R	14	2	12	Moderate flexion	Good	Severe	−
Case 35	F	E.H.	L	10	2	8	None			
Case 36	M	G.B.	L	6	9 mo.	5	Flexion			
Case 37	M	E.R.	R	8	1	7	None			
Case 38	F	P.D.	L	10	6 mo.	9	Moderate flexion	Normal	Moderate	−
Case 39	F	M.K.	R	6	2	4	None	Good	Moderate	−
Case 40	M	E.N.	R	9	1	8	Moderate flexion	Good	Moderate	+
Case 41	F	C.O.	L	5	1	4	None	Normal	Moderate	0
Case 42	M	C.M.	L	12	3	9	25° flexion			
Case 43	F	B.R.	R	10	6 mo.	9	Flexion	Poor	Severe	−
Case 44	F	L.H.	L	16	4	12	None			
Case 45	F	M.M.	L	9	4	5	50° flexion			
Case 46	F	H.F.	R	12	6 mo.	11	Moderate flexion			
Case 47	F	H.F.	L	12	6 mo.	11	Moderate flexion			
Case 48	F	M.T.	R	10	5	5	None	Good	Moderate	0
Case 49	F	E.H.	R	10	2	8	None			
Case 50	M	O.D.	L	9	7	2	None			
Case 51	F	C.T.	R	11	1	10	60° flexion			
Case 52	F	M.S.	R	11	3	8	45° flexion	Fair	Moderate	+
Case 53	M	B.P.	L	6	2	4	Flexion			
Case 54	M	J.R.	R	11	3	8	Slight flexion			
Case 55	M	D.H.	R	13	5 mo.	12	60° flexion			
Case 56	F	E.V.	L	13	6	7	Moderate flexion			
Case 57	M	R.R.	R	8	3	5	None			
Case 58	F	R.R.	L	11	6	5	Severe flexion			
Case 59	F	E.M.	L	14	6	8	45° flexion			
Case 60	F	W.B.	L	10	9 mo.	9	90° flexion	Fair	Severe	+
Case 61	M	C.E.	L	16	5	11	70° flexion			
Case 62	M	C.L.	L	12	1	11	None	Good	Moderate	−
Case 63	M	C.M.	R	12	3	9	30° flexion			
Case 64	M	J.H.	R	9	2	7	None			
Case 65	F	B.S.	L	10	3	7	Moderate flexion			
Case 66	M	J.B.	L	14	4	10	90° flexion	Fair	Moderate	+
Case 67	F	M.J.	R	8	3	5	None	Good	Moderate	+
Case 68	F	A.H.	R	10	3 mo.	10	Slight flexion	Fair	Severe	+
Case 69	F	A.H.	L	10	3 mo.	10	Moderate flexion	Fair	Moderate	−
Case 70	F	B.B.	R	7	1	6	Severe flexion	Fair	Severe	+
Case 71	F	F.R.	L	17	7	10	Severe flexion	Fair	Moderate	+
Case 72	M	R.K.	R	11	3	8	90° flexion	Fair	0	−
Case 73	M	R.K.	L	11	3	8	90° flexion	Poor	0	+
Case 74	M	R.H.	R	7	1	6	45° flexion	Fair	Moderate	−
Case 75	M	J.V.D.	L	13	3	10	None	Good	Moderate	0

TABLE II. Clinical findings in seventy-five cases of paralyzed hips which did not dislocate. Nomenclature as in Table I.

TABLE II—*Continued*

CONDITION OF MUSCLES

		Internal Rotators	*Flexors*	*Adductors*	*Abductors*	*Gluteus Maximus*	*External Rotators*	*Tensor Fasciae Latae*	*Quadriceps*	*Inner Hamstrings*	*Outer Hamstrings*
0	Case 19	Fair	Good	Good	0	Good	Fair	0	Fair	0	0
0	Case 20	0	Fair	0	0	Good	Good	0	Fair	Fair	0
	Case 21	0	0	0	0	Good	Fair	0	0	Good	0
	Case 22	Fair	Fair	Fair	0	Good	Fair	0	Good	0	0
	Case 23	Fair	Fair	0	0	Good	Good	0	0	Good	Good
+	Case 24	Fair	Good	0	Good	Good	Good	Good	0	Normal	Normal
+	Case 25	Good	Good	Fair	Good	Good	Good	Normal	0	Good	Good
−	Case 26	0	Normal	Good	Fair	Good	Good	0	0	Good	Normal
+	Case 27	0	0	0	0	Good	Fair	0	0	0	0
0	Case 28	Fair	Good	0	Good	Good	Good	Normal	0	Good	Good
0	Case 29	Fair	Good	Fair	0	Good	Good	0	0	Fair	Fair
−	Case 30	Good	Fair	Good	Fair	Good	Good	Fair	Good	Good	Good
	Case 31	Good	Fair	Good	0	Good	Normal	0	Normal	Fair	0
0	Case 32	Fair	0	0	Fair	Fair	Good	0	0	0	0
0	Case 33	Good	0	0	Good	Fair	Normal	0	0	Fair	0
−	Case 34	Fair	Good	Fair	0	Fair	Good	0	Fair	0	0
	Case 35	0	0	0	0	Fair	0	0	0	0	0
	Case 36	0	0	0	Fair	Fair	0	Fair	0	0	0
	Case 37	0	Good	Good	0	Fair	Fair	0	Fair	Fair	0
−	Case 38	Fair	0	0	0	Fair	Good	0	0	Good	Good
−	Case 39	Fair	Good	Fair	0	Fair	Good	0	0	Fair	Fair
+	Case 40	Fair	Normal	0	Good	Fair	Good	Good	0	0	Good
0	Case 41	0	0	0	0	Fair	0	0	0	Fair	Fair
	Case 42	0	0	0	0	Fair	Fair	0	0	0	0
−	Case 43	Fair	Fair	Fair	Fair	Fair	Fair	Normal	0	Fair	Fair
	Case 44	Fair	Fair	Good	0	Fair	Good	0	Good	Good	Good
	Case 45	0	0	Fair	0	0	0	0	0	0	0
	Case 46	0	0	0	0	0	0	0	0	0	0
	Case 47	0	0	0	0	0	Good	0	0	0	0
0	Case 48	0	0	0	0	0	Fair	0	0	0	0
	Case 49	0	0	0	0	0	0	0	0	0	0
	Case 50	Good	Good	Good	0	0	Good	0	Fair	Fair	Fair
	Case 51	0	0	0	0	0	0	0	0	0	0
+	Case 52	0	Good	0	0	0	Good	0	0	Fair	Good
	Case 53	0	0	0	0	0	0	0	0	0	0
	Case 54	0	0	0	0	0	0	0	0	0	0
	Case 55	0	Fair	0	0	0	0	0	0	Fair	0
	Case 56	0	0	0	0	0	0	0	0	0	0
	Case 57	0	0	0	0	0	0	0	0	0	0
	Case 58	0	0	0	0	0	0	0	0	0	0
	Case 59	0	Good	0	0	0	Fair	0	0	0	0
+	Case 60	0	0	0	0	0	0	0	0	0	0
	Case 61	0	Good	0	0	0	0	0	0	Fair	Fair
−	Case 62	0	0	0	0	0	0	0	Fair	0	0
	Case 63	Fair	0	0	0	0	0	0	0	Fair	0
	Case 64	0	0	0	0	0	0	0	0	0	0
	Case 65	Fair	Fair	Fair	0	0	Good	0	0	0	0
+	Case 66	0	0	0	0	0	0	Good	0	0	0
+	Case 67	0	0	0	0	0	Fair	0	0	0	0
+	Case 68	0	0	0	0	0	0	0	0	0	0
−	Case 69	0	0	0	0	0	0	0	0	0	0
+	Case 70	0	Fair	0	0	0	Fair	0	0	0	0
+	Case 71	0	0	0	0	0	0	0	0	0	0
−	Case 72	0	0	0	0	0	0	0	0	0	0
+	Case 73	0	0	0	0	0	0	0	0	0	0
−	Case 74	0	0	0	Fair	0	Good	0	0	0	0
0	Case 75	0	0	0	0	0	0	0	0	0	0

infantile paralysis which have been brought to the hospital for treatment, an incidence of a little over two and five-tenths per cent.

The records and x-rays of these twenty-six hips were reviewed and the more pertinent clinical findings were tabulated (Table I). Then a series of seventy-five hips with extensive paralysis, but in which dislocation had not occurred, was selected at random from the hospital records and the clinical findings were tabulated in a similar manner (Table II).

Examination of Table I reveals the fact that in our series dislocation was more common on the right side, there being seventeen cases on the right side and only nine cases on the left side, while bilateral dislocation occurred in only one instance. Sex was not an important factor as the cases were about equally divided between the two sexes. The duration of the disease was important as dislocation did not occur in any case in which the paralysis had not been present for at least four years and in the majority of the cases it occurred in children in which the disease began in infancy. However, neither the age at onset nor the duration of the disease can be considered as definite causes of the condition, because in Table II there are listed a large number of severely paralyzed hips in which the disease began in infancy and in which the paralysis had been present five years or more and yet dislocation had not occurred. The average age at onset in the two groups is approximately the same.

In regard to the presence or absence of deformities, there was a difference between the two groups as only four of the twenty-six hips in which dislocation occurred did not present deformities, while in the similar group of severely paralyzed hips in which dislocation did not occur approximately half of the cases presented no deformity. As a rule, the deformities were flexion deformities and varied from slight permanent flexion to permanent flexion of ninety degrees. This, however, was true in both groups and the percentage of severe deformities was greater in the group in which dislocation did not occur.

It is particularly interesting to note that in many cases the deformity did not correspond to what would be expected from the muscle examination and that severe deformities, even as great as ninety degrees of permanent flexion, might be present in flail hips. Consequently it is obvious that our current belief that deformities are largely the result of muscle imbalance is not entirely true as regards the hip. For instance, in Case 2 of Table I there was a flexion deformity of sixty degrees in the presence of a good gluteus maximus muscle and a good flexor group at the hip. In other words, according to our muscle examination, the flexors and extensors in this case were about balanced and yet the deformity occurred. The same situation occurred in several of the flail hips where, with complete paralysis of the flexors, deformities of from fifty to ninety degrees were present. While it cannot be denied that muscle imbalance plays an important rôle in the production of deformities, it must be admitted that other factors may be of equal importance. We believe that habitual posture was responsible for the deformities in many of our cases.

FIG. 1

X-ray of pelvis in Case 24, Table I. Acetabulum good, severe coxa valga, slight varus deformity of the pelvis.

Our interest was directed especially to the results of the muscle examinations as we believed that the distribution of the paralysis was the important factor in determining whether or not dislocation would eventually occur. We believed that the most important muscle in the prevention of paralytic dislocation at the hip was the gluteus maximus, because all of the cases were posterior dislocations and in all cases the dislocation could be produced by flexing and adducting and internally rotating the hip. In this group we had no cases of anterior dislocation and no cases in which the dislocation occurred in abduction, extension, and external rotation. Consequently, we have arranged our cases in a descending scale as regards the power present in the gluteus maximus,—that is, in the extensors of the hip.

The muscle examination of the hip included the internal rotators, flexors, adductors, gluteus maximus (extensors), external rotators, tensor fasciae latae and abductors. In addition to the above we have also charted the quadriceps and hamstrings. The internal rotators, flexors, and adductors have been placed in sequence and are believed to be the muscles which tend to produce dislocation when they are active and when the gluteus maximus, external rotators, tensor fasciae latae and abductors are paralyzed. We have thus divided the muscles of the hip into two main divisions, the first of which tends to cause dislocation while the second tends to prevent dislocation. We may regard the quadriceps as an accessory muscle of flexion and the hamstrings as accessory muscles of extension at the hip. However, we do not believe that the presence

or absence of power in these muscles has very much to do with the stability of the hip joint.

In our muscle examination we have recognized only four degrees of power: normal, good, fair, and zero. "Zero" includes those muscles which are completely flail and those in which there is only a trace of power left, but in which this power is not sufficient to move the joint with all resistance removed. "Fair" includes those muscles which are able to move the joint without resistance, but are not able to lift the limb against gravity. "Good" muscles are those which can lift the limb against gravity, but which cannot take much added resistance, while the "normal" muscle groups are those which to all intents and purposes have normal power for the individual,—that is, they can move against gravity and resistance. We have not used spring balance tests, because our records are not made that way and we are not in a position to give the power of the various groups in pounds. However, the muscle examinations were made by skilled physiotherapists and were checked by the surgeons in charge and we believe them to be satisfactory.

We were surprised to note that in six of the twenty-six cases in which dislocation occurred the gluteus maximus was good, and in five additional cases it was fair,—that is, in eleven of the twenty-six cases dislocation occurred in the presence of definite power in the extensor group. Much the same is true of the external rotators. Apparently the muscles which are most important in lending stability to the hip are the abductors and the tensor fasciae femoris, as dislocation occurred in only two cases with fair abductors and in only three cases with a fair tensor fasciae femoris and in no cases in which these muscles were good or normal. However, it is to be emphasized that these muscles were more frequently paralyzed than any other group, both in the cases with dislocation and in those in which dislocation did not occur.

It is further to be noted that in only one case of the entire group was there a good tensor fasciae femoris in the presence of severe abductor paralysis. It is obvious from this that we rarely have the opportunity

TABLE III

Muscle Groups	Hips That Dislocated				Hips That Did Not Dislocate			
	Normal	Good	Fair	0	Normal	Good	Fair	0
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Internal rotators..	3.8	7.6	30.4	57.6	2.6'	13.3	26.6	57.6
Flexors.....	3.8	38.4	15.2	42.2	0.8	24.0	17.3	50.6
Adductors.....	15.2	19.2	22.8	42.2	2.6	14.6	14.6	67.2
Abductors.....	0	0	7.6	92.3	0.3	13.3	13.3	72.0
Gluteus maximus..	0	22.8	19.2	57.6	10.6	30.6	17.3	40.3
External rotators..	3.8	34.2	19.2	42.2	8.0	41.3	16.0	34.6
Tensor fasciae latae.	0	0	11.4	88.6	5.3	8.0	6.6	80.0
Quadriceps.....	3.8	34.2	3.8	57.6	5.3	8.0	10.6	76.1
Inner hamstrings..	0	30.4	19.2	49.8	5.3	20.6	25.3	48.8
Outer hamstrings..	0	22.8	11.4	65.2	6.6	21.3	13.3	64.8

Table III. Percentage of the various muscle groups which were normal, good, fair, and zero in twenty-six paralyzed hips which dislocated and in seventy-five paralyzed hips which did not dislocate.

TABLE IV

Muscle Groups	Dislocating Hips	Hips That Did Not Dislocate
Internal rotators	0.58	0.61
Flexors	1.04	0.90
Adductors	1.08	0.52
Average of three preceding groups	0.90	0.68
Gluteus maximus	0.65	1.11
External rotators	1.00	1.23
Tensor fasciae latae	0.11	0.39
Abductors	0.08	0.44
Average of four preceding groups	0.48	0.79
Average of all muscle groups	0.69	0.73

Table IV. Average power present in the various muscle groups of twenty-six paralytic hips which dislocated and seventy-five paralytic hips which did not dislocate. Normal is 3, good is 2, fair is 1, and zero is 0.

of transplanting the tensor fasciae femoris into the trochanter for abductor paralysis.

We have manipulated the figures obtained from the muscle examination of the two groups in various ways and in Table III we have presented the percentage of the muscle groups in the two series in which the muscles were normal, good, fair, and zero. It will be seen from these tables that the internal rotators were approximately the same in the two groups, while the adductors and flexors were slightly stronger in the group in which dislocation occurred; likewise, the abductors and external rotators and gluteus maximus were stronger in the group in which dislocation did not occur.

By denoting the power in the various muscle groups by numbers and considering normal as 3, good as 2, fair as 1, and zero as 0, we have computed the average power of each muscle group for the entire series. These results are given in Table IV. It is seen that, if we average the power of the internal rotators, flexors, and adductors, we find that the average power of these muscles was 0.90 in the hips which dislocated as contrasted with an average power of 0.68 in the hips which did not dislocate. Likewise, if we average the power in the gluteus maximus, external rotators, tensor fasciae femoris, and abductors, we find that the average power of this second group was 0.48 in the hips which dislocated and 0.79 in the hips which did not dislocate.

From the above it is evident that taken as a group the twenty-six hips which dislocated were characterized by relatively strong flexors, internal rotators, and adductors and relatively weak extensors, external rotators, and abductors. That is, the above was true when these hips were compared with a similar group in which dislocation did not occur. That the two groups are comparable is evident from the fact that the average power of all muscles in the twenty-six hips which dislocated was 0.69 and the average power of all muscles in the seventy-five hips which did not dislocate was 0.73. Thus the average muscle power in each group

FIG. 2

X-ray of pelvis in Case 23, Table I. Acetabulum fair, moderate coxa valga, and definite varus deformity of the pelvis.

was less than fair, which is 1, and the difference between the two groups was 0.04.

From Table IV we can formulate a rule that severely paralyzed hips with relatively strong flexors, adductors, and internal rotators and relatively weak extensors, external rotators, abductors and tensor fasciae femoris may be expected to dislocate. It is further evident that relatively strong adductors combined with relatively weak abductors and tensor fasciae femoris are especially liable to result in dislocation.

However, examination of Tables I and II reveals many exceptions to the above rules. In seeking an explanation for these exceptions we have studied the available roentgenographs of the pelves and hips of both series in order to determine whether or not the form of the pelvis and hip could be considered a causative factor in the dislocation.

The points to which we paid particular attention were the depth of the acetabulum, the tilt of the pelvis, and the angle of the neck of the femur. In considering these factors we have classified the acetabula as poor, fair, good, and normal. Since in all of the femora the angle of the neck was increased we have classified these as severe, moderate, and slight coxa valga. As regards the tilt of the pelvis, we have classified these as varus, valgus, and normal pelves. It is to be noted that by a varus or valgus pelvis we mean one in which the os innominatum as a whole is

deviated inward or outward, and we do not refer to a bending inward of the ischium as varus.

The terminology which we have used in classifying these pelves is best understood by referring to Figures 1, 2, and 3.

In Figure 1 is shown a paralytic hip which dislocated and in which the acetabulum is good, but not quite normal. In this case there is a severe coxa valga—that is, the neck of the femur is almost in line with the shaft and the pelvis is approximately normal, although it might be considered as showing a slight varus deformity.

In Figure 2 is shown a hip in which the acetabulum is considered fair. This acetabulum is fairly deep and fairly well formed. There is a moderate coxa valga and definite varus deformity of the pelvis.

In Figure 3 is shown a hip in which the acetabulum is poor. It is quite shallow and definitely offers inadequate support for weight-bearing. In addition to this there is severe coxa valga and a valgus deformity of the pelvis,—that is, slight flaring of the pelvis so that the acetabulum faces almost directly outward.

In considering these three factors it is evident that the better the acetabulum the more stable the hip. We have also assumed that the more nearly normal the angle of the neck of the femur, the less likely is

FIG. 3

X-ray of the pelvis in Case 1, Table I. Acetabulum poor, severe coxa valga, and a valgus deformity of the pelvis.

dislocation to occur; and we have considered that a varus deformity of the pelvis would tend to prevent dislocation, while a valgus deformity would tend to promote dislocation, as a varus deformity would tend to render the floor of the acetabulum more nearly horizontal, while a valgus deformity would tend to render it more nearly vertical and thus the latter would lessen the stability of the hip.

In Table V are shown the results of the x-ray studies on twenty-three of the dislocating hips and forty-four of the hips which did not dislocate. From this table it is evident that the acetabula were much poorer in the hips which dislocated. Likewise, severe coxa valga was more marked in the hips which dislocated. On the other hand, the tilt of the pelvis apparently had relatively little to do with the condition. In other words, the hips in which paralytic dislocation occurred tended to have poor acetabula and severe coxa valga when compared with a similar group of severely paralyzed hips. However, we are not in a position to state that the dislocation was the result of the abnormalities in the contours of the pelvis and femur, because it is obvious that these abnormalities may be the result rather than the cause of the dislocation.

We have also studied the heads of the femora in our cases and were surprised to find that, while they tended to be small as a result of the atrophy of disuse, they presented relatively slight deviations from the normal in contour.

TREATMENT OF PARALYTIC DISLOCATION

Prevention. Probably the most important factor in the treatment of these cases is prevention. Our observations indicate that the position of flexion, adduction, and internal rotation is a vicious one in severely paralyzed hips. Consequently we believe that all patients with severe paralysis at the hip, and especially those in which the abductors, external rotators, and extensors are paralyzed, should spend much of their time in a position of abduction, extension, and external rotation. In other words, flexion and adduction deformities should be prevented by conservative methods and these patients should acquire the habit of sitting and sleeping with the knees separated, as we believe that abduction is even more important than extension in preventing dislocation. If this plan is consistently adhered to, we feel that relatively few paralyzed hips will dislocate regardless of the distribution of the paralysis.

In our twenty-six cases the treatment was as follows:

Eight cases are still under observation. Two of these are too young for operation and in one the general condition is so poor that operation cannot safely be undertaken at this time. One is on the waiting list to enter the hospital for operation and four are being treated in abduction with the hope that the tendency to dislocate will subside. One case was not treated because the paralysis was so severe that we thought stabilization of the hips would be useless as it would not be possible to get the patient up on her feet even after the hips had been stabilized. One patient

TABLE V

Dislocating Hips						Hips That Did Not Dislocate					
Acetabulum		*Coxa Valga*		*Tilt of Pelvis*		*Acetabulum*		*Coxa Valga*		*Tilt of Pelvis*	
Poor	15	Severe	16	Varus	7	Poor	2	Severe	15	Varus	18
Fair	6	Moderate	6	Valgus	8	Fair	11	Moderate	22	Valgus	12
Good	2	Normal	1	Normal	8	Good	22	Normal	7	Normal	14
Normal	0					Normal	9				

TABLE V. Deformities in the pelvis and the neck of the femur present in the x-rays of twenty-three paralyzed hips which dislocated and of forty-four paralyzed hips which did not dislocate.

gets along fairly well with crutches and braces and the dislocation causes relatively little trouble. Consequently operation is not contemplated at this time. In one case the tendency of the hip to dislocate disappeared after treatment in abduction. This we regard as a cure by conservative means. In one case there was a spontaneous recovery,—that is, a hip which could formerly be dislocated at will is now stable and it is not possible to produce dislocation. Operation was recommended in fourteen cases. Six of these refused operation and consequently were not treated. Eight of the cases were operated upon.

In all of the operated cases the operation performed was a shelf operation. In most instances the shelf was taken from the side of the ilium. In one instance one of us (J. A. K.) secured a graft for a shelf from the tibia by the simple method of taking a curved gouge and driving it into the bone from below upward so that a wide curved graft was lifted up. Then, beginning about two inches higher, the gouge was driven from above downward so that the curved graft was removed entirely from

FIG. 4

X-ray of the pelvis in Case 10, Table I. Acetabulum poor, severe coxa valga, and normal tilt of the pelvis. Small shelf made from curved tibial graft. Result good three years after the operation.

FIG. 5

X-ray of pelvis in Case 8, Table I. Acetabulum poor, severe coxa valga, and valgus deformity of the pelvis. Large shelf taken from the ilium. Result good three years after the operation.

the bone. With the concave periosteal surface downward one edge of the graft was set into a groove above the rim of the acetabulum (Fig. 4).

In seven of the shelf operations the results were good. In one it was only fair. Although in this case the hip was quite stable the shelf was placed so high that it did not prevent the head of the femur from riding up on the superior margin of the acetabulum. It is interesting to note that every shelf operation was different and that the clinical result was just as good in the cases in which a small shelf had been accurately placed as in the cases in which a large shelf had been folded downward from the ilium. In other words, the size of the shelf seemed to have relatively little to do with the success of the procedure (Figs. 4 and 5). It is, of course, possible that the immobilization in abduction which followed the shelf operation had a good deal to do with the ultimate success in some of the patients.

SUMMARY

A comparison of twenty-six paralytic dislocations of the hip with seventy-five severely paralyzed hips which did not dislocate reveals the fact that no definite type of paralysis was responsible for the dislocation, but that dislocation was most frequent in hips with strong flexors, adductors, and internal rotators and weak extensors, abductors, and external rotators. Of the above muscle groups the abductors appeared to be the most important in maintaining the stability of the hip as we had no cases in which dislocation occurred in the presence of good abductors.

A study of the x-rays of these cases revealed the fact that in paralytic hips which had dislocated the acetabulum was poor and severe coxa valga was usually present. However, it is to be emphasized that these deformities were probably the result of the paralysis and dislocation rather than the cause, as we do not believe that there were any congenital abnormalities in these cases.

We were impressed by the fact that nearly all of the hips which dislocated presented a definite deformity. As any severely paralyzed hip is liable to dislocate, we believe that the prevention of deformities is especially important in these cases. We were further impressed by the fact that the deformities were not always the direct result of muscle imbalance, but in many cases seemed to have been the result of habitual posture. Consequently, we believe that patients with severely paralyzed hips should spend much of their time with the hips in a position of extension and abduction and external rotation.

Operative treatment should be considered in those cases in which conservative treatment has failed or in which there is no reasonable hope that conservative treatment (that is, correction of deformities and maintenance of abduction) will lead to a cure. Contra-indications to operation are such poor general condition that the operation would be unusually dangerous, and such extensive paralysis that even with a stable hip it would not be possible for the patient to walk on crutches and braces. The operation recommended is the shelf operation and we believe that an accurate placing of the shelf is more important than its size, as we have found small shelves just as efficient as large ones.

A NEW METHOD OF DETERMINING PRESENCE OF UPWARD DISPLACEMENT OF THE GREAT TROCHANTER*

BY NATHAN H. RACHLIN, M.D., BROOKLYN, N. Y.

The usual procedure of examining by measuring from the anterior-superior spine of the ilium to the inner malleolus indicates only relative shortening as compared with the opposite side, and is so prone to error, even in experienced hands, that no two measurements are alike, especially in obese people.

Likewise, the method of utilizing Nélaton's line is for the same reason uncertain and has an added disadvantage, that of moving the patient about.

Bryant's triangle does not give us landmarks of sufficient prominence to guide us correctly in all cases.

The method described here is based upon the linear alignment of the crests of the pubic bones in relation to the great trochanters. The procedure is as follows: draw a horizontal line across the crests of the pubic

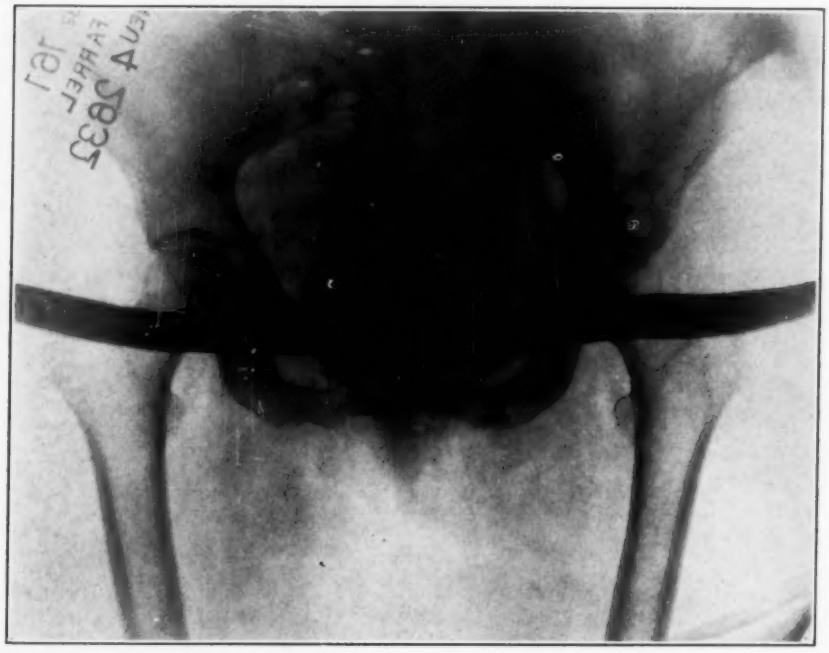

FIG. 1

Shows roentgenographic view of these landmarks in a normal pelvis.

* From the Orthopaedic Services of the Kings County, Neurological, and Beth Moses Hospitals.

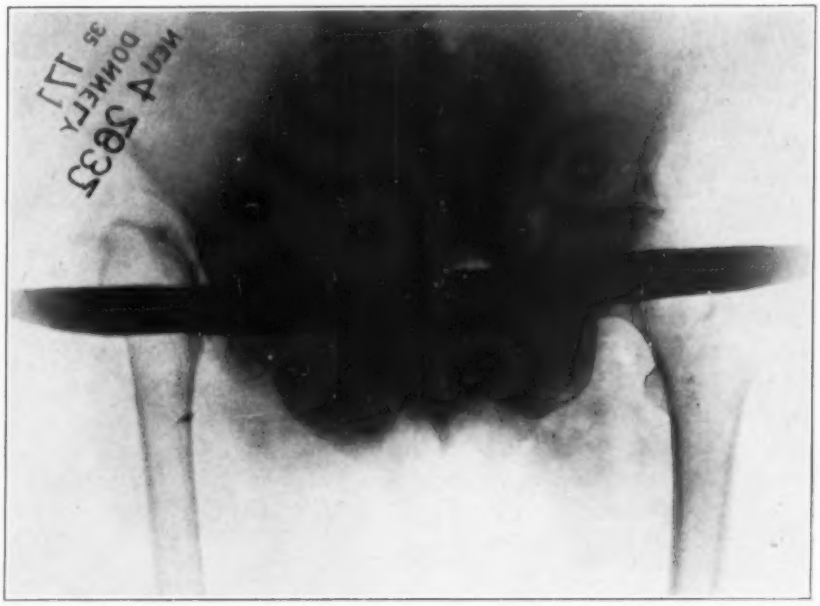

FIG. 2

Shows the disturbed relations in a fractured hip.

bones, at right angles with the umbilicus. This will, on its outer aspect, be opposite the prominent and most palpable part of the great trochanters and about one-half to three-quarters of an inch below their superior borders. These findings were confirmed by a clinical study, checked by roentgenograms.

Variations from this rule are noticed in patients who have exceptionally narrow pubic bones, which necessarily brings their level down to a lower horizontal plane, and in those who have exaggerated posterior curving of the sacra, as in spondylolisthesis, etc., thus raising the plane of the trochanters to a higher level. However, the relative position of the trochanters in relation to each other can still be located with certainty.

This method commends itself because of its simplicity and the ease of finding the landmarks even in very fat people.

Cases where one or both trochanters are markedly above the indicated line would strongly suggest upward displacement of the heads of the femora.

A NEW TREATMENT OF INTRACAPSULAR FRACTURES OF THE NECK OF THE FEMUR AND CALVÉ-LEGG-PERTHES' DISEASE*

BY E. J. BOZSAN, M.D., F.A.C.S., NEW YORK, N. Y.

From the Division of Skeletal Surgery, Morrisania City Hospital, New York

In spite of the best modern efforts, union in some cases of intracapsular fractures of the neck of the femur, in the young as in the aged, is not obtained. An explanation of this failure as well as a method to overcome it has not as yet been found. Cancellous bone unites rapidly and firmly. Failure of fragments of cancellous bone to unite when brought in apposition, in cases of intracapsular fracture, may, perhaps, be explained as follows: The proximal fragment, though apparently one piece, is made up of two segments,—one is the true head, the other is a portion of the neck. The two are separated by a boundary line situated at the site of the epiphyseal plate. The blood supply from the round ligament as it traverses the obstacle of this boundary line is markedly diminished. The distal segment of the proximal fragment, because of this fact, degenerates, becomes partially necrotic, and loses the capacity for callus formation. How soon this occurs after accident is under investigation. If wide communication between the two sections of the proximal fragment is afforded and wider openings through the distal fragment are made, propensity of the cancellous bone for union will be reestablished.

The method of obtaining the desired communication and increasing the circulation is to establish minute channels throughout the length of the neck of the femur from the body of the greater trochanter, well into the head, and so to establish an artificial irrigating system.

The first trial was successful. The good result was the more striking as the case was that of a patient whose intracapsular fracture had been discovered only four weeks before, and the operation was not performed on account of the general condition of the patient until six weeks after the accident, when there was considerable absorption in the neck as demonstrated by the x-ray findings.

It would seem that, if firm bony union resulted in a case fraught with the above mentioned handicaps, it might be reasonably hoped that, if the operation were performed soon after the accident at the time of reduction, a similar good result might follow.

Case 1. Miss E. C. (21316), aged fifty-four, suffered an accident on May 7, 1931. She was treated in a private hospital for the consequences of a fractured skull; she was totally unconscious most of the time, and disoriented at the time of her admission to the Morrisania City Hospital on June 3, 1931. The left foot was in marked eversion and some shortening existed. A roentgenogram of the left hip, taken on June 4, revealed a complete intracapsular fracture of the neck. The drilling operation was

*Cases presented on November 10, 1931, before the Clinical Society of the Hospital for Joint Diseases, and February 9, 1932, at the Morrisania City Hospital before the New York Fracture Committee.

FIG. 1

Case 1. Roentgenogram, taken June 4, 1931, shows a complete intracapsular fracture with marked external rotation of the shaft, and the distal fragment displaced in front of the proximal.

FIG. 2

Case 1. Roentgenogram, taken June 24, 1931, during attempts at improving reposition after operation; indicates a marked area of absorption in the distal fragment.

FIG. 3

Case 1. Shows the best reposition obtained June 27, 1931.

FIG. 4

Case 1. Roentgenogram, November 27, 1931, shows complete and firm bony union of the two fragments.

FIG. 5

Case 2. Roentgenogram, taken August 29, 1930, shows the very early beginning of the process in the head.

FIG. 6

Case 2. Roentgenogram of January 13, 1931, reveals the destruction at its height; shows a large sequestrum in the periphery of the head and absorptive changes in the whole head and part of the neck.

FIG. 7

Case 2. Roentgenogram, taken November 5, 1931, reveals the sequestrum well healed in the head; the outline of the head almost entirely spheric, flattened only at the site of the former sequestrum, the density of the head restored, and absorptive areas filled out.

performed on June 17 and, after repeated attempts to improve the apposition of the fragments, a plaster cast was applied on June 23, and the patient was confined in this for sixteen weeks. At the end of the eighth week, the cast was bivalved, the anterior shell was removed, and cautious passive and active exercises were performed daily until the patient was able to execute straight leg raising when out of the posterior shell. At the end of the sixteenth week, a straight caliper brace was applied, and the patient was allowed to walk about on crutches. The brace and the crutches were gradually discarded and the patient was walking with the aid of a cane seven months after the operation. The roentgenograms (Figs. 1, 2, 3, and 4) here reproduced represent the different stages.

The adoption of the same method of treatment for Calvé-Legg-Perthes' disease was based on my conception of this disease, or rather of a group of pathological manifestations in the neck and head of the femur as being secondary changes, due to impairment of circulation caused by traumatic compression-planes in the neck and on the head. The detailed explanation and illustration of this conception cannot be given space in this brief report.

Upon conveying a fresh blood supply to the affected areas, cessation of degenerative changes may be expected. The first case fully confirmed this expectation.

Case 2. Miss S. R. (7665), aged twelve, suffered a minor accident while bobsleighing, in March, 1930. Slight disability of the right hip developed during the months of June and July and she was treated in the Out-Patient Department of the Morrisania City Hospital. As the disability progressed, and the roentgenograms, taken on August 29, 1930, revealed degenerative bone changes in the neck and head of the right femur, the patient was repeatedly seen at the same hospital until December 3, 1930. As the roentgenograms revealed rapid progress of the degenerative process in the head and neck after several examinations, including tuberculin tests, the drilling operation of the neck and head was performed January 31, 1931. Three longitudinal channels were drilled in the axis of the neck from the greater trochanter into the head, and two transverse channels from the trochanter into the neck. A plaster spica was applied after which cautious, gradual active and passive exercises were performed daily and the patient was discharged May 2, 1931, with completely free motions and painless weight-bearing at the right hip joint. An x-ray follow-up revealed rapid restoration of the destroyed areas in the head. Patient presented herself last on February 9, 1932, at which time she walked without pain or limp and all motions were equally free in both hip joints. The accompanying roentgenograms (Figs. 5, 6, and 7) reveal the three outstanding stages in the development and recovery.

Since January, 1931, this operation has been performed twenty-four times for intracapsular fracture of the neck of the femur and nine times for different forms of degenerative processes in the neck and head of the femur with uniformly satisfactory results. Obviously, however, a minimum of eight to ten months is required for a definite and clear demonstration of the results, and therefore the reports of the other cases cannot be included in this communication, which is published with an appeal for trial.

CONGENITAL FUSION OF THE BONES OF THE FOOT; WITH A REPORT OF A CASE OF CONGENITAL ASTRAGALOSCAPHOID FUSION

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Assistant Orthopaedic Surgeon, Hospital for Ruptured and Crippled

Congenital fusion of certain bones of the body is seen at times without causing any symptoms. This condition is mainly found in bones undergoing gradual regressive development, the joints between these bones having very little mobility,—for example: the normally present fusion of the sacral and coccygeal vertebrae of the human skeleton.

The joints of the human foot have suffered a great loss of mobility as compared with the clasping foot of the primates. This was necessary since man adopted upright posture, and the human foot had to provide a firm foundation for the body.

A number of cases of congenital fusion of the bones of the foot have been recorded. The most commonly observed is the fusion of the two distal phalanges of the fifth toe. Congenital fusion may occur in the joints between metatarsals and cuneiforms, the cuneiform and cuboid, the calcaneum and scaphoid, the astragalus and calcaneum, and the astragalus and scaphoid, the latter being extremely rare. Also, multiple combination of these fusions may be found.

Engel reported two cases of multiple and bilateral fusion of bones in hands and feet, where astragaloscaphoid fusion was also present.

Lagrange described a case of, what he thought to be, a congenital fusion of the foot joints. In a cadaver of a woman forty-six years of age both scaphoids were fused with the three cuneiforms, and the second and third metatarsals were in turn fused with the cuneiforms; the cuboids were also fused with the fourth and fifth metatarsals.

Leboucq discussed calcaneoscaphoid and astragalocalcaneal fusions. He proved that this condition may undoubtedly be of congenital nature, due to failure of development of the articular cavity during the differentiation of the embryonic cartilages. Leboucq saw calcaneoscaphoid fusion in a foetus of twenty-five millimeters, and astragalocalcaneal fusion in one of sixty-five millimeters.

Pfitzner, Morestin, Dwight, Zoja, Slomann, Badgley, Bargellini, Esau, Wagoner, and others reported cases of congenital fusion of the bones of the feet.

The congenital astragaloscaphoid fusion should be considered as an extremely rare and unusual occurrence, because even such thorough students of the variation of the foot skeleton as Pfitzner and Dwight have

* From the Service of Dr. Leo Mayer.

never seen a single case of a real congenital fusion between the astragalus and the scaphoid. Pfitzner observed only one case of astragaloscaphoid fusion,—in one foot (left) of a woman sixty-four years of age with marked osteo-arthritic changes. After thorough maceration of the foot skeleton, he was able to separate the astragalus from the scaphoid bone.

The only case of astragaloscaphoid fusion described by Morestin was also not of congenital nature. He believed it to be due to an old infection.

Anderson, dissecting a cadaver of a man thirty-four years of age with unavailable clinical history, found bilateral astragaloscaphoid fusion. He published this case in 1879, and it seems to be the first case of real congenital astragaloscaphoid fusion reported. According to Anderson "In carnivora, cheiroptera, and many rodents (mus, castor, hydrochoerus), and in many insectivora, a scapholunar bone is present. In pteropus of the cheiroptera, the cuneiform unites with the scapholunar in the foot. In crocodilia the scaphoid and astragalus coalesce to form an astragalo-navicular bone. . . . In the carpus, the scaphoid and lunar unite (carnivora), scapholunar and cuboid (pteropus), scaphoid and trapezium (sloth and megatherium). In comparing the bones of the carpus and tarsus, the astragalus may be regarded as the homologue of the lunar (Vicq d'Azyr), or as corresponding to the united scaphoid and semi-lunar (Gegenbaur). The scaphoid in the foot, on the other hand, may be regarded as equivalent to the scaphoid in the hand. . . ."

Thus, the astragaloscaphoid fusion observed in the human foot may possibly be considered a homologue of the scapholunar bone of the carpus of carnivora.

In 1918 Holland described two cases which, he thought, were "the rarest varieties of the congenital abnormalities" of the tarsus and the carpus. These were the first two cases that he had ever seen in twenty-one years' experience as roentgenologist, watching for the abnormalities of the extremities. The first case presented multiple fusion between tarsal and metatarsal bones of the right foot in a man thirty-three years of age. The left foot was clinically and roentgenologically perfectly normal. This case is a rather doubtful one in regard to congenital origin of the fusion, as in early childhood the patient had had some operative intervention on the right foot; there had been also a scar and extreme pain and tenderness on mere touching over the dorsum of his right foot ever since the patient could remember. On the contrary, Holland's most interesting second case of a woman twenty-one years of age with bilateral and symmetrical fusion of tarsal and carpal bones is undoubtedly a congenital anomaly. There was fusion of astragaloscaphoid and calcaneocuboid joints, and the second and third metatarsals were fused to their respective cuneiform bones. The carpal bones also presented bilateral anomalies. In May 1928 a case of unquestionable congenital astragaloscaphoid fusion (only in the right foot) was published by Illievitz. His patient, a boy seventeen years of age, had only four metatarsal bones on the right foot, while the left one presented no abnormalities.

In December 1928 Bullitt reported a case of bilateral congenital astragaloscaphoid fusion in a man thirty-five years of age. This condition was an incidental discovery during roentgenographic examination for sprained ankle. It is interesting that the roentgenograms also showed bilateral presence of a very large accessory scaphoid.

A most instructive observation, illustrating how very cautious one should be in pronouncing the fusion of foot joints as congenital, was made by Haglund. He described a case of a young lady, twenty-two years of age, who at the age of eleven was his patient, suffering with tuberculosis of the left astragaloscaphoid and scaphocuneiform joints. She was treated with immobilization by means of a plaster casing and was completely cured. Thirteen years later, when reexamined as a matter of follow-up, the patient presented, roentgenographically, the most perfect astragaloscaphoid fusion, without the slightest suggestion of preexisting tuberculosis. Haglund showed in his article the original roentgenograms and the ones taken thirteen years later, and concluded that this case could be very easily mistaken for a congenital fusion. Nothing was said about the right foot, but presumably it was normal.

On August 5, 1930, a girl, nine years of age, was seen by the writer at the Foot Department of the Hospital for Joint Diseases, complaining of "lumps" over the medial aspect of her feet. The child's mother first noticed the "lumps" about three years before admission when the girl was six years of age, and stated that the prominences had been gradually growing larger. There was no history of any previous injury of the feet or any sickness. The patient had occasional pain due to pressure of the shoe against the prominent part of the foot, but she could walk without any discomfort. The girl was the youngest in a family of two children, and had a perfectly normal brother thirteen years of age. Both parents were alive and quite healthy. There was no history of any deformities in the family. The patient had always been quite well, except for the usual diseases of childhood.

On examination it was found that the patient was a perfectly healthy and well developed child. Her feet were moderately pronated with fairly well preserved longitudinal arches. There was a bony projection (Fig. 1) about two centimeters in diameter over the medial aspect of each foot, corresponding to the location of the medial tuberosity of the scaphoid bone. The projections were covered with a bursa and somewhat reddened skin, but they were not tender. There was a slight limitation of supination and adduction of the forefoot somewhat more

FIG. 1

Shows moderate pronation of the feet, and a large projection over the region of the scaphoid tubercle.

FIG. 2-A

Anterior-posterior view of the same feet showing complete astragaloscaphoid fusion. Note the outline of the soft tissues (retouched) over the projecting medially astragaloscaphoid bones.

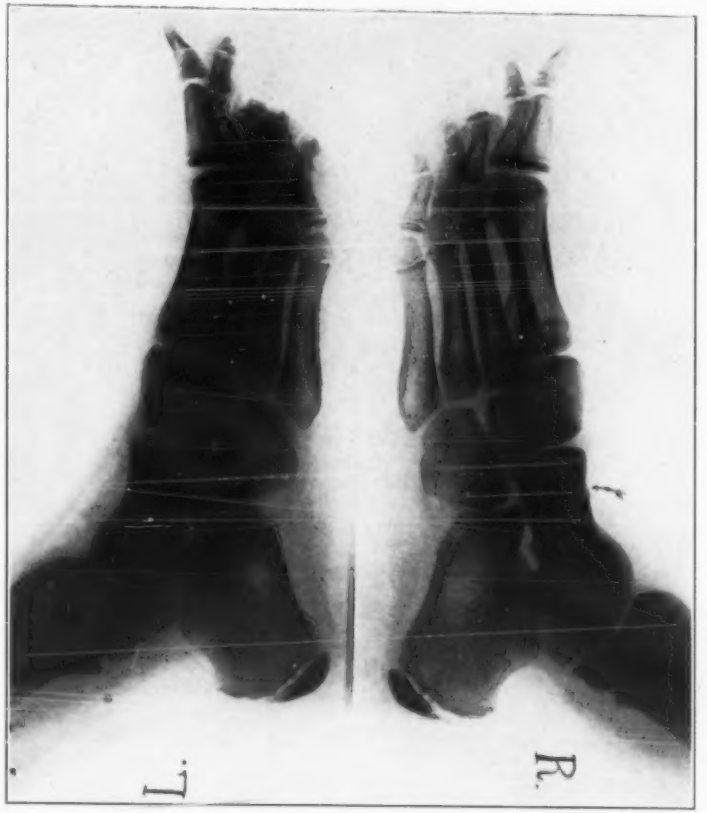

FIG. 2-B

Lateral view. Complete astragaloscaphoid fusion of the left foot; there is a suggestion of a joint line (arrow) over the dorsal aspect between the right astragalus and the scaphoid.

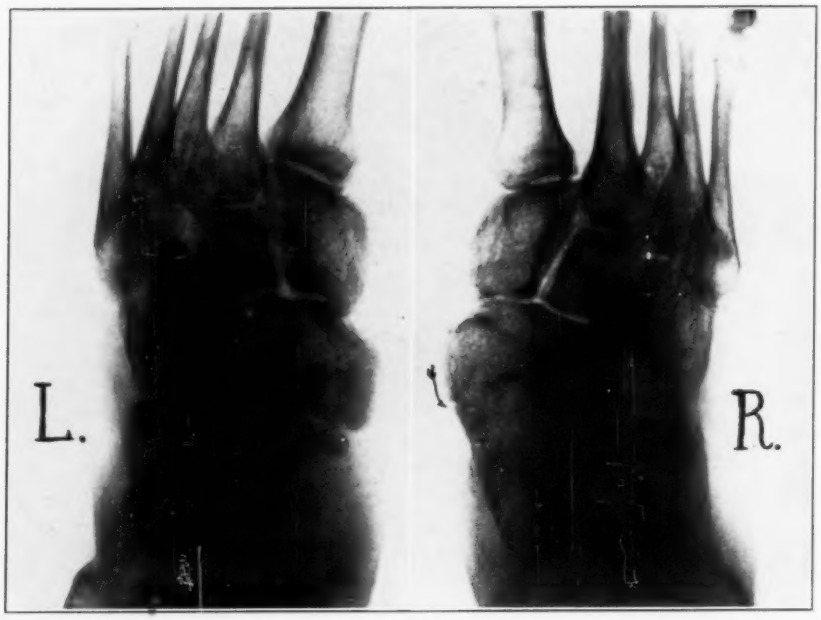

FIG. 3-A

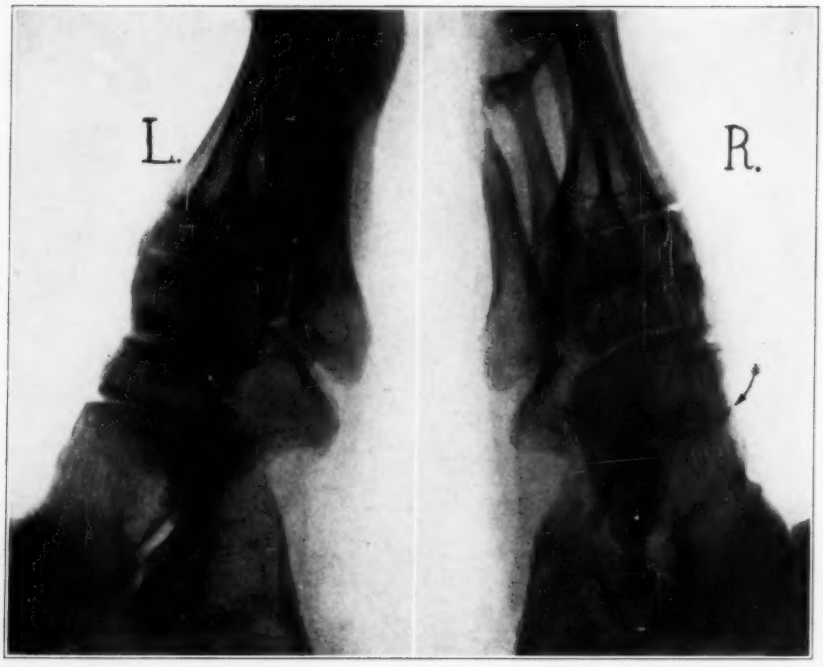

FIG. 3-B

Anterior-posterior and lateral views of feet in a case of traumatic fusion of the right astragaloscaphoid joint. The line of the joint (arrow) can still be made out. Note marked osteo-arthritic changes in the right foot. Large accessory scaphoid is shown on the anterior-posterior view of the left foot.

marked on the right side. Outside of that, all passive and active motions of feet and gait were perfectly normal. The pulsation of both foot arteries were palpable on their usual location. The writer, on first examination, was under the impression that the child had unusually large accessory scaphoids, and only the roentgenograms of the feet (Figs. 2-A and 2-B) revealed the true nature of her condition. The patient was admitted to the Hospital (History No. 29104) and the medial projecting part of the astragaloscaphoid bones was chiseled off. There was some hypermobility in the mid-tarsal joints for a few months following the operation. She wore foot plates for about a year and a half after the operation.

When last seen on January 23, 1932, the patient was quite comfortable; the feet were fairly normal except that a slight pronation was still present. The roentgenographic examination of the feet of both parents and of the patient's brother showed no abnormalities.

The patient's carpal bones were not roentgenographed.

To the best of the writer's knowledge this case is the third recorded where only bilateral congenital fusion of the astragaloscaphoid joint was present, other tarsal joints being normal. After a thorough review of the literature only two similar cases (mentioned above) were found; one reported by Anderson * and the other by Bullitt, the former not quite complete as there were no roentgenograms available in 1879.

The writer recently treated a man about thirty years of age, with the right foot markedly pronated, abducted, and completely flat, due to an injury seven years previously. The roentgenograms (Figs. 3-A and 3-B) showed an almost complete right astragaloscaphoid fusion with marked productive osteo-arthritic changes. This case is included in this paper in order to illustrate the pathological astragaloscaphoid fusion as compared with the congenital.

SUMMARY

1. Congenital fusion of the bones of the feet is rare; the astragaloscaphoid fusion being extremely unusual.

2. Pathological fusion may sometimes simulate a congenital one.

3. One case of bilateral congenital astragaloscaphoid fusion is reported.

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NOTES ON AMPUTATIONS CONNECTED WITH CIRCULATORY DISTURBANCES OF THE EXTREMITIES

BY STEELE F. STEWART, M.D., LOS ANGELES, CALIFORNIA

I feel that most workers in the field of the circulatory diseases of the extremities have become convinced that there are two elements, at least, in every circulatory disease:

(1). A spasmodic element under the control of the sympathetic nervous system.

(2). An organic element affecting the vessel walls.

The ratio between the two is rather indeterminate clinically.

It is because of the vasomotor spasm that one is justified in performing a sympathectomy for the amelioration of these diseases. It would seem that the earlier the blood supply to the part was increased the more one could anticipate the return of that part to approximately normal function, and possibly also an arrest of the arterial disease by an increased circulation through the vasa vasorum.

That these two elements are the sole factors involved in any circulatory disease we may not believe, as is well illustrated by a patient on whom we operated several years ago.

R. B. had a thrombo-angiitis obliterans. This had affected the lower extremities, but subsequently involved both upper extremities. The distal phalanx of the left third finger showed marked discoloration to a definite level just distal to the joint line. This finger was amputated just proximal to the line of demarcation and both the patent phalangeal arteries had to be tied because of their great size. In spite of such a large circulation, the tissue at the site of amputation sloughed for a short distance.

It is an unfortunate thing to amputate a finger or toe and have the sloughing continue back into the foot or hand, necessitating a mid-leg or mid-arm amputation. It is obvious that Nature forms a delicate line of demarcation between life and death and that if surgical interference, such as we have outlined, causes still greater sloughing, then the life or death of adjacent tissues hangs by a slender thread.

It would seem therefore that: (1) in gangrene of the extremities unaccompanied by arterial sclerosis of a degree demonstrable by x-ray, sympathectomy should be done in order to increase to the greatest possible extent the circulation of that quadrant; (2) as the slough that accompanies many of these cases of phalangeal gangrene is exceedingly slow in separating, the slough should be removed as largely as possible, *keeping on the necrotic side of the line of demarcation* and thus in no way interfering with Nature's delicate plan of life.

In our experience, the sloughing is most easily separated by frequent soaking of the extremity in a warm solution of magnesium sulphate. No definite data can be given as to temperature or saline concentration as the

pain accompanying too great heat or too strong a solution is almost unbearable and varies from time to time, and the patient has to regulate these two factors according to his sensations. When the slough is finally separated, the granulating tissues may be gently drawn together by adhesive bands. Suturing is inadvisable for reasons above indicated.

Sloughing involving the dorsum of the foot practically always requires mid-leg amputation. In our experience, mid-thigh amputations are seldom required. However, the case originally referred to in this discussion taught an interesting lesson. One of the lower extremities had to be amputated because of much sloughing of the dorsum of the foot. We anticipated a mid-leg amputation which we did, but were surprised to find that, while all the tissues were healthy in appearance except the anterior tibial muscle, which somewhat resembled a fish, scarcely fifteen drops of blood came from the leg in fifteen minutes without the use of tourniquet, hemostats, or compresses. This condition compelled a mid-thigh amputation, and it revealed that there is a wide difference in the requisite blood supply for life and activity.

THE NORMAL AND PATHOLOGICAL PHYSIOLOGY OF THE NUCLEUS PULPOSUS OF THE INTERVERTEBRAL DISC*

An Anatomical, Clinical, and Experimental Study

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This paper is presented to the members and guests of the American Orthopaedic Association as a careful study and confirmation of the excellent work of Schmorl on the intervertebral disc. The intervertebral disc with its pulpy center is of fundamental importance in the normal and pathological physiology of the spine. An appreciation of the development, anatomy, physiology, and pathology of this structure is necessary for the intelligent interpretation and management of all conditions affecting the spine which we as clinicians are called upon to treat.

THE ANATOMY OF THE INTERVERTEBRAL DISC

Anatomists have described the intervertebral disc as far back as Vesalius [1] in 1555. It remained however for von Luschka [2] to give an accurate description of its structure and embryology. Bardeen [3], in his studies of the development of the spine, postulated as to its physiological importance. No clinical nor pathological observations were made until Schmorl [4], a pathologist of Dresden, described the frequent prolapses of the disc into the adjacent vertebral bodies.

THE DEVELOPMENT OF THE SPINE

The physiological and pathological significance of the intervertebral disc can not be well appreciated without some knowledge of the developmental and structural anatomy. This was first carefully reported by von Luschka [2] who traced the development of the notochord and the formation of the intervertebral disc in 1858. Kölliker [5], in 1859, noted that the central portion of the intervertebral disc in a one-year-old child contained residual notochord cells. In 1879, Löwe [6] found that the entire nucleus pulposus of the rat was formed by the notochord. Leboucq [7], in 1880, believed, from his studies of human and other mammalian embryos, that the notochord tissue was practically destroyed long before birth. This we know is not true. Virchow [8] (1857) and Dursy [9] (1869) suggested that the nucleus pulposus was formed by degeneration of the annulus fibrosus fibers. Bardeen, in 1905, and Williams [10], in 1908, wrote extensive studies of the development of the spine, and more recently

*Read before the American Orthopaedic Association, at Toronto, Canada, June 18, 1932.

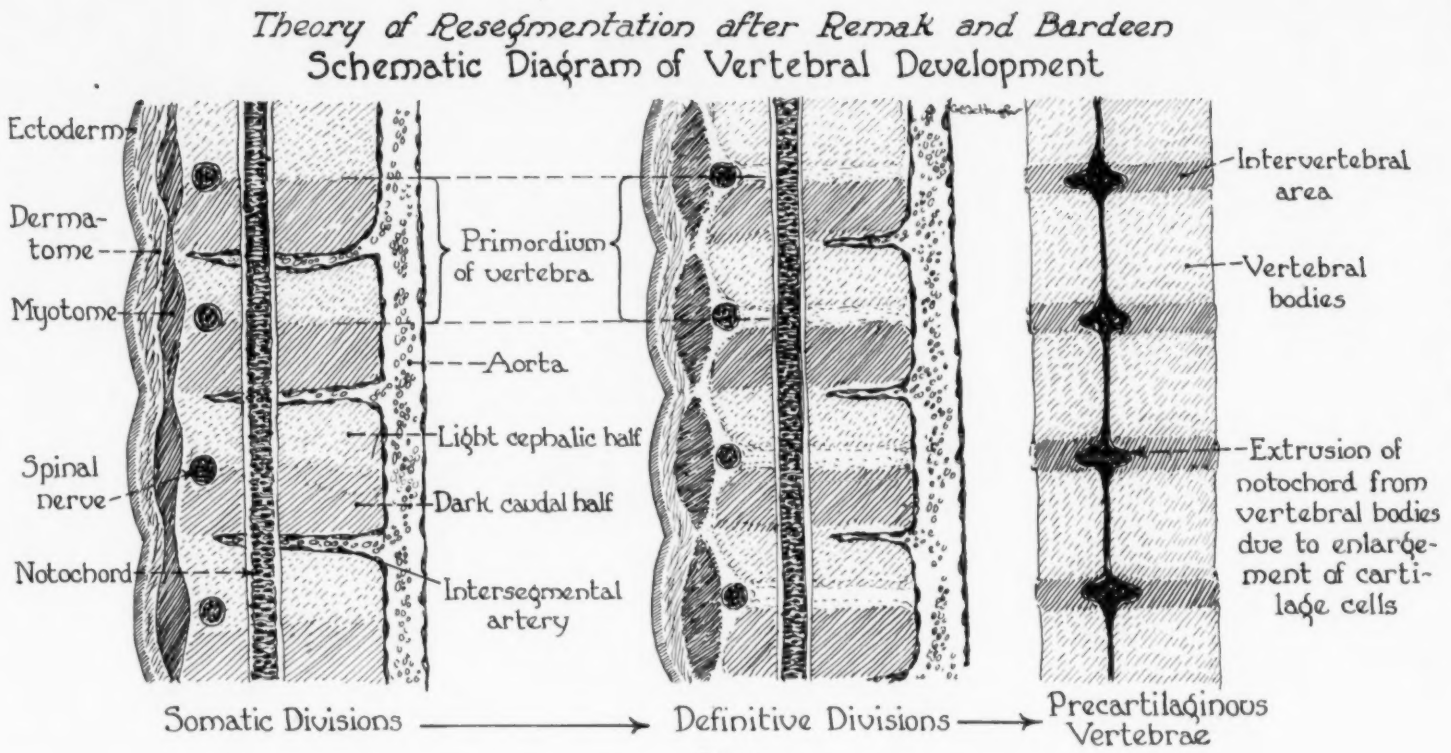

FIG. 1

A diagrammatic sketch illustrating the vertebral development after the theory of Ramak and Bardeen.

Schmorl, Calvé and Galland, and Beadle have made additions to this subject.

The definite origin of the notochord is not well established. Kollman [11], Bardeen, and Minot [12] state that at a very early period of the embryo there is a thickening of the entoderm in the mid-sagittal plane known as the chordal plate. This ridge of cells in a human embryo of two and eleven-hundredths millimeters was described by Kollman. The chordal plate is gradually pinched off from the entoderm and is then known as the notochord.

A migration of mesenchymal cells occurs from the sclerotomes to surround the notochord (Figs. 1 and 2).* Remak [13] and Bardeen believe these cells arrange themselves in a segmented column in accordance with the primitive segmentation of the embryo, each vertebral segment or protovertebra being marked off by the entrance of the intersegmental artery. Bardeen believes that each protovertebra develops a condensed caudal and a light cephalic half and that the definitive vertebra is then formed by the union of the condensed caudal half of the protovertebra above with the light cephalic half of the protovertebra below (Fig. 3). Williams, however, does not accept this theory of resegmentation. He states that, following the migration of the mesenchymal cells about the notochord, there is no period of condensation and formation of protovertebrae. He concludes from his studies that the segmentation of the vertebrae is entirely definitive. The early demarcation of the vertebrae is the result of differential growth and not condensation. The mesenchymal cells, composed almost entirely of nucleus, begin to add cytoplasm rapidly in the region of the vertebral bodies, while little change is noted in the intervertebral area. Thus the intervertebral regions, composed of nuclear material, appear condensed.

Our studies lead us to the following conclusions concerning this phase of the development of the spine. We differ somewhat with, yet bring together and confirm, the views of both Bardeen and Williams. The mesenchymal cells of the schlerotome migrate to surround the notochord. These cells form a segmented column, the segments of which are marked off above and below by the entrance of the intersegmental arteries. Each segment shows a massing of these cells laterally into two groups,—a light cephalic mass and a darker caudal mass. The cells nearer the intersegmental arteries receive more nutrition than those farther removed, and hence are more rapid in their differentiation. Therefore the cephalic mass of the segment below and the caudal portion of the caudal mass of the segment above rapidly add cytoplasm, merge, and become the anlage of the vertebral body. The cranial portion of the caudal mass, being the

* The illustrations as prepared by the author showed the exact magnification of most of the photomicrographs. In order to preserve the author's grouping, in having the half-tones made it has been necessary to reduce the illustrations to conform to the size of *The Journal* page. With each legend has been included a note showing the reduction of the illustration, as published, from the original illustration prepared by the author. This reduction should be taken into consideration in determining the magnification of the photomicrograph.

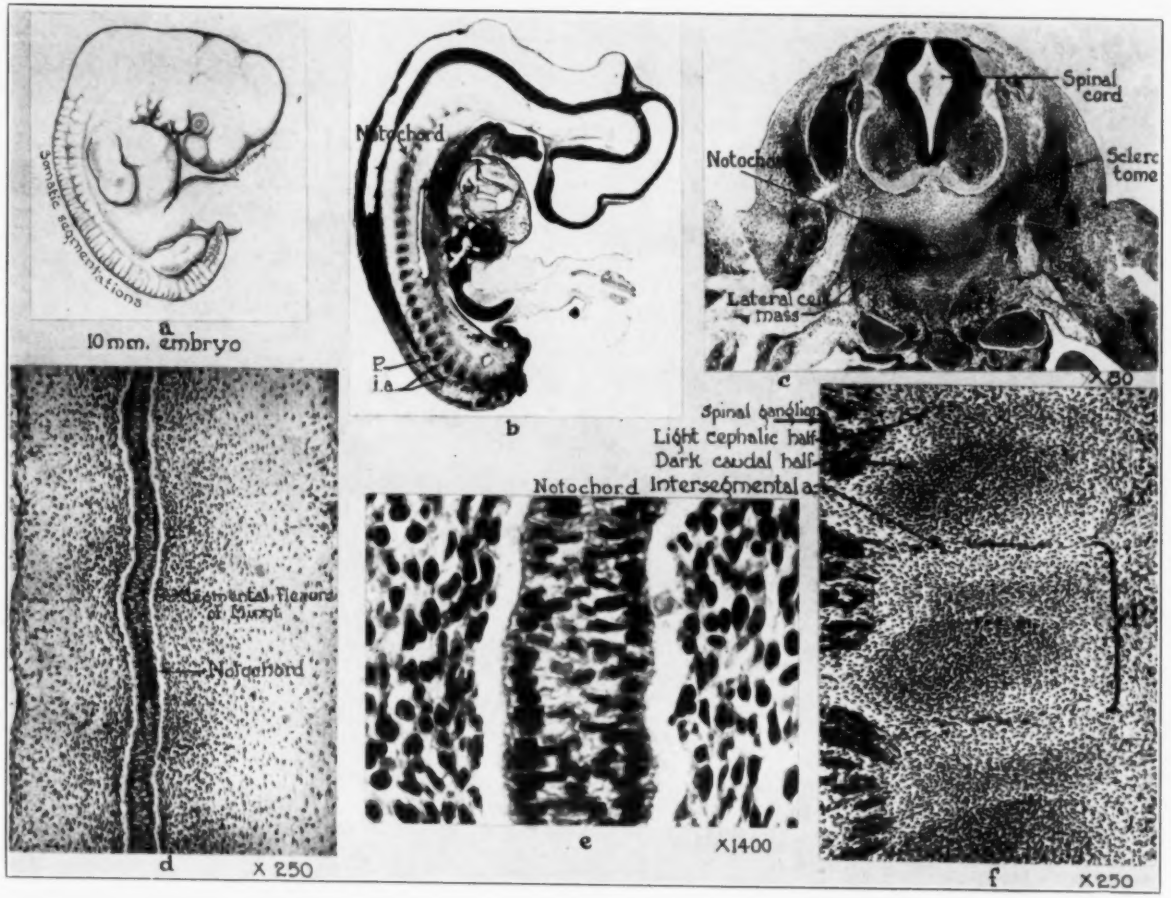

FIG. 2

A human embryo of ten-millimeters (five weeks). (Two-fifths size of original illustration.)

a. Lateral view of specimen showing somatic segmentation.

b. Mid-sagittal section of specimen. *P*. primitive segment or protovertebra; *i.a.* intersegmental artery. Notochord with segmental flexures of Minot. For detailed structure of notochord see sections *d*. and *e*. The primitive segmentation (protovertebrae) of Bardeen is well demonstrated in the caudal portion of this specimen with advancement toward the definitive stage cephalically. These segments are marked off above and below by the intersegmental arteries. (See section *f*.) Note the light cephalic half and dark caudal half of each protovertebra and the beginning differentiation and addition of cytoplasm of these two areas in the region of the intersegmental artery.

c. Mid-dorsal cross section. Note the migration of the mesenchymal cells

FIG. 2 (*Continued*)

from the schlerotome to surround the notochord. These cells are massed laterally, leaving the true mid-sagittal plane relatively less dense; this is apparent in section *d*. which is cut in the true mid-sagittal plane.

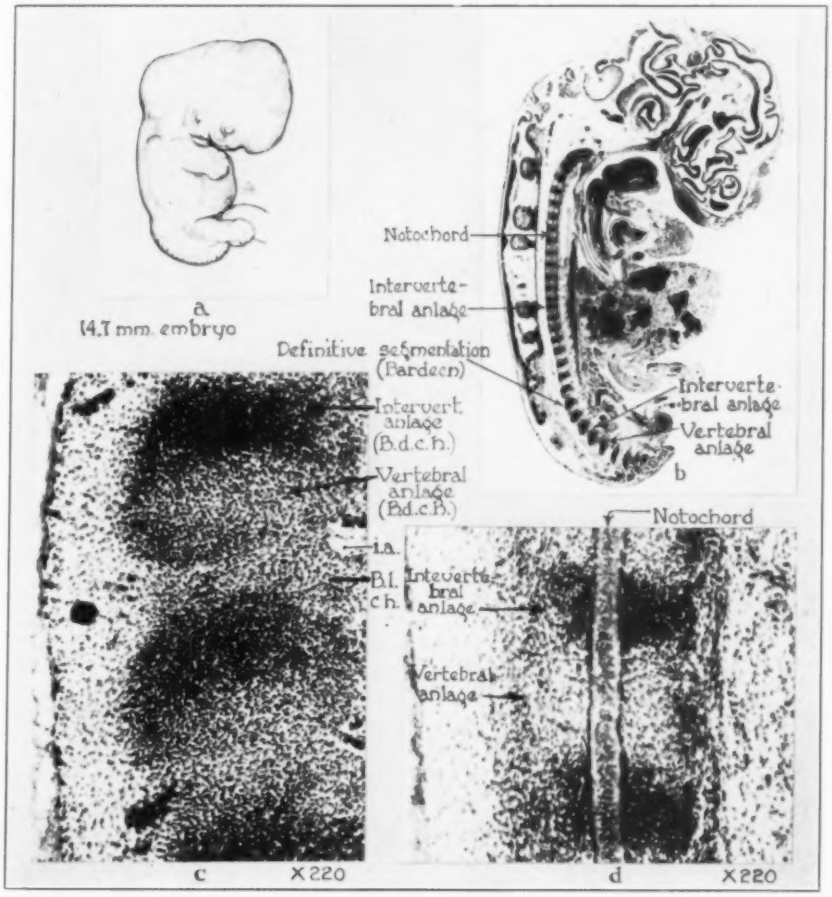

FIG. 3

A human embryo of fourteen and seven-tenths millimeters (six-and-one-half-weeks). (Two-fifths size of original illustration.)

a. Lateral view of specimen.

b. Mid-sagittal section of specimen. The notochord displays little change from that seen in the five-week embryo of Fig. 2. The vertebral development, however, shows definite advance toward the definitive form. Here again we note that the cells of the light cephalic half of the protovertebra below and those of the caudal part of the dark caudal half of the protovertebra above (or those cells surrounding the intersegmental artery) are adding cytoplasm, merging and forming the definitive vertebral anlage. The cells of the cephalic portion of the dark caudal half remain as a dense nuclear mass, the intervertebral disc anlage. The higher magnifications in *c*. and *d*. bring this out more clearly. *B.d.c.h.* the dark caudal half of the protovertebra after Bardeen; *B.l.c.h.* the light cephalic half of the protovertebra after Bardeen; *i.a.* intersegmental artery.

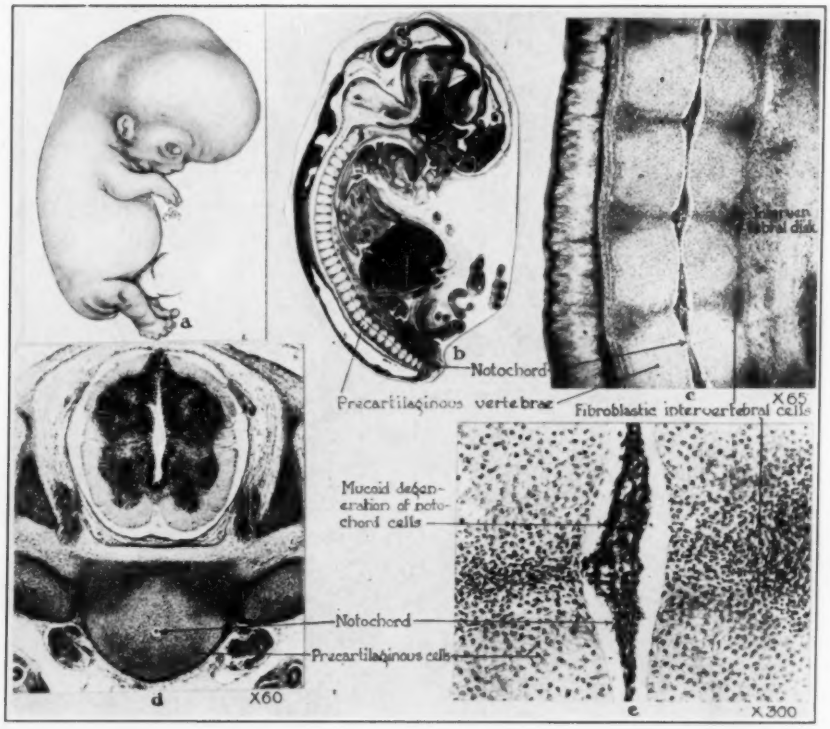

FIG. 4

A human embryo of twenty-one millimeters (seven and one-half weeks). (One-third size of original illustration.)

a. Lateral view of specimen.

b. Mid-sagittal section of specimen. The cells of the vertebral bodies contain a large amount of cytoplasm, but as yet there is no intercellular matrix. We, therefore, speak of this as the precartilaginous stage. See sections *c.*, *d.*, and *e.* The intervertebral regions have shown relatively less histological change, the cells are, however, elongating into fibroblastic type. The notochord cells are being squeezed from the vertebral into the intervertebral regions and show mucoid material both intracellular and extracellular.

d. A mid-dorsal cross section traversing vertebral body. The notochord may be seen as a small area in the center of the body.

furthest removed from the source of nutrition (the intersegmental artery), remains undifferentiated as the anlage of the intervertebral disc. It is of interest that this portion of the spine remains avascular throughout developmental and adult life.

With the rapid addition of cytoplasm to the cells of the vertebral regions, there occurs a marked difference in the pressure exerted upon the notochord. The cells of this structure begin to be extruded into the intervertebral regions where the pressure is less (Fig. 4). Mucoid degeneration of the notochord cells appears. This mucoid material may be found both extracellular and within the cells as vesicles. The cells of the intervertebral region now begin to differentiate into an elongated fibroblastic type and are arranged along a vertical axis, attaching above and below to the vertebral bodies.

In the embryo of ten weeks (Fig. 5), the cells of the vertebral bodies have developed into typical cartilage cells, and ossification centers are now present. The cells of the notochord have been entirely extruded from the vertebral region and are now confined to the central portion of the intervertebral disc. The old site of the notochord in the vertebral bodies is marked only by a streak of mucoid material. Centrally this is entirely obliterated by the ossification centers. We may speak, henceforth, of the notochord material as the nucleus pulposus and of the surrounding fibrocartilage as the annulus fibrosus. The fibers of the annulus fibrosus are becoming better defined and may be seen to be attached centrally above and below to the cartilaginous vertebral bodies immediately about the old notochord site. They are bulged out laterally in the midportion of the disc by the enlarging nucleus pulposus. Thus the nucleus pulposus material does not come in direct contact with the adjacent surfaces of the vertebral bodies, but is separated by a layer of fibrocartilage arising from the intervertebral disc substance. This is an important

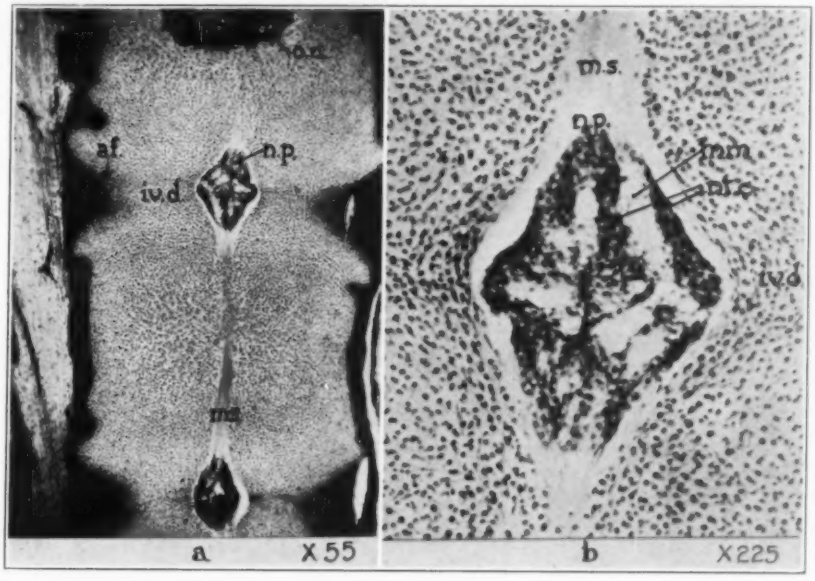

FIG. 5

A human embryo of fifty-seven millimeters (ten weeks). (One-half size of original illustration.)

a.f. annulus fibrosus; *n.p.* nucleus pulposus; *i.v.d.* intervertebral disc; *o.c.* ossification center; *m.s.* mucoid streak remnant of the notochord; *m.m.* mucoid material; *nt.c.* notochord cells.

The notochord cells are entirely extruded from the vertebral into the intervertebral region. Only a mucoid streak marks the old site of the notochord in the vertebrae. Ossification centers are now forming in the vertebral bodies and these entirely destroy all traces of the notochord. The fibroblastic intervertebral cells are bulged out centrally, though they maintain their original site of attachment to the cartilaginous vertebral bodies. Thus they form a fibrocartilaginous envelope separating the nucleus pulposus from direct contact with the cartilage of the vertebral bodies.

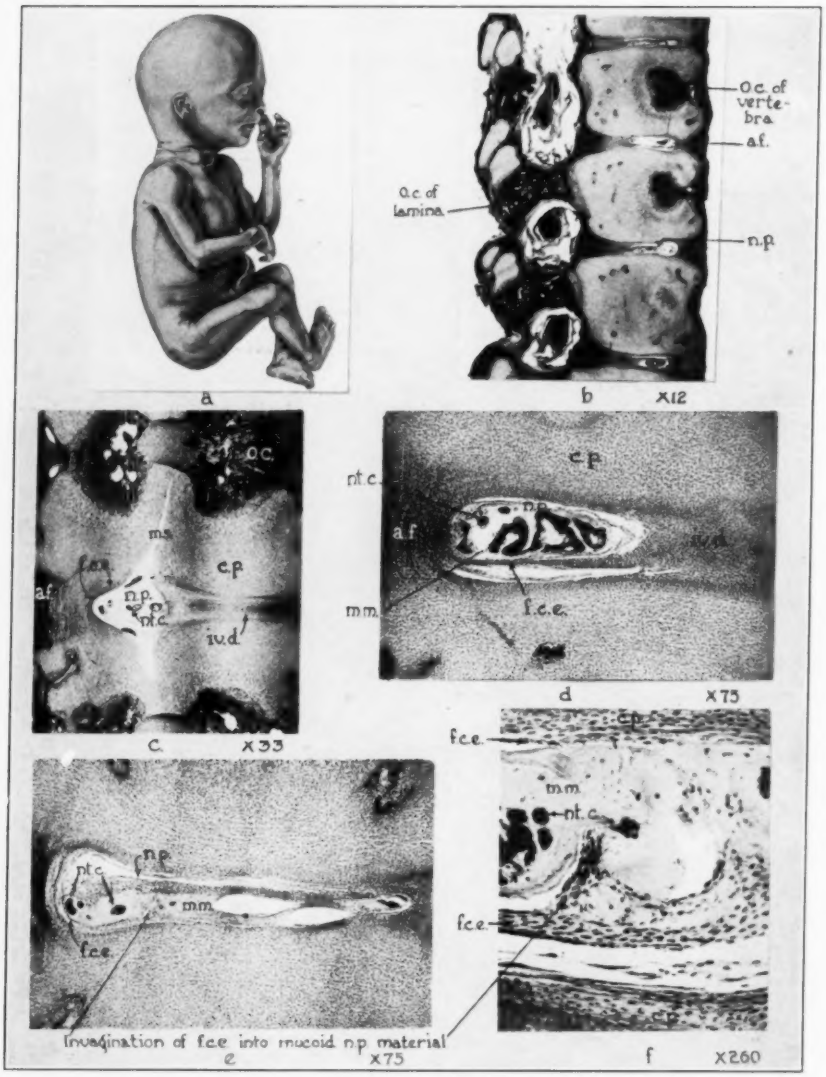

FIG. 6

A human embryo of one hundred and fifty-seven millimeters (eighteen weeks). (One-third size of original illustration.)

a.f. annulus fibrosus; *n.p.* nucleus pulposus; *o.c.* ossification center; *m.s.* mucoid streak; *f.c.e.* fibrocartilage envelope; *i.v.d.* intervertebral disc; *nt.c.* notochord cells; *m.m.* mucoid material; *c.p.* cartilage plate.

a. Lateral view of specimen.

b. Mid-sagittal section of specimen. The intervertebral discs in this specimen show a definitely fibrous annulus fibrosus surrounding a large mucoid nucleus pulposus. The fibers of the annulus fibrosus immediately surrounding the nucleus pulposus are clear and sharply staining, and maintain their original attachment to the cartilage plate around the mucoid streak marking the old site of the notochord. (See section *c.*) They form thereby a fibrous or fibrocartilaginous envelope about the nucleus pulposus, separating this body from direct contact with the cartilage plate. Invaginations from this fibrocartilage envelope are seen invading the mucoid nucleus pulposus material, sections *e.* and *f.*

d. An estimate of the large amount of notochord cells still present may be gathered from this section.

observation in connection with the later development of the nucleus pulposus.

In the embryo of eighteen weeks (Fig. 6), the mucoid tract seen in Figure 4 is still present. A still greater increase in size and mucoid content of the nucleus pulposus is noted. The fibrocartilage envelope shows in its central portion invaginations invading the mucoid material. This, we believe, with Robin [14], is the origin of the fibrous tissue found in such quantity in the adult nucleus pulposus. We also call attention to the clearly outlined and sharply stained annulus fibrosus fibers which immediately surround the nucleus pulposus material. Demonstration of these fibers in the eighteen-week embryo disproves the theory of Dursy and Virchow that the degeneration of the annulus fibrosus fibers is the chief source of the nucleus pulposus material. It should also be noted in this eighteen-week embryo that more actual notochord material is present in

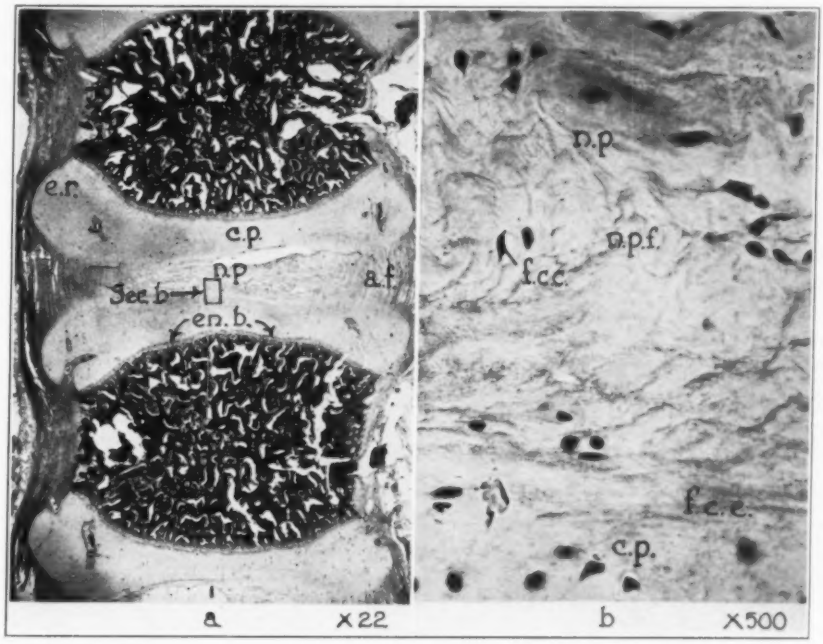

FIG. 7

A full-term human foetus. (One-half size of original illustration.)

a.f. annulus fibrosus; *n.p.* nucleus pulposus; *c.p.* cartilage plate; *e.r.* epiphyseal ring; *en.b.* enchondral bone formation; *f.c.c.* fibrocartilage envelope; *f.c.c.* fibrocartilage cells; *n.p.f.* nucleus pulposus fibers.

a. Mid-sagittal section of spine, through the first and second lumbar vertebrae and intervening disc. Note the growth zone where enchondral bone formation is extending across the entire bone end, both in the region of the epiphyseal ring and cartilage plate proper.

b. A high magnification of the area where the nucleus pulposus gradually merges into the cartilage plate. This gradual merging is the result of the extension of the fibers from the fibrocartilage portion of the cartilage plate, the fibrocartilage envelope, into the nucleus pulposus. The cartilage plate is formed of a hyaline cartilage adjacent to the bone and a fibrocartilage adjacent to the intervertebral disc.

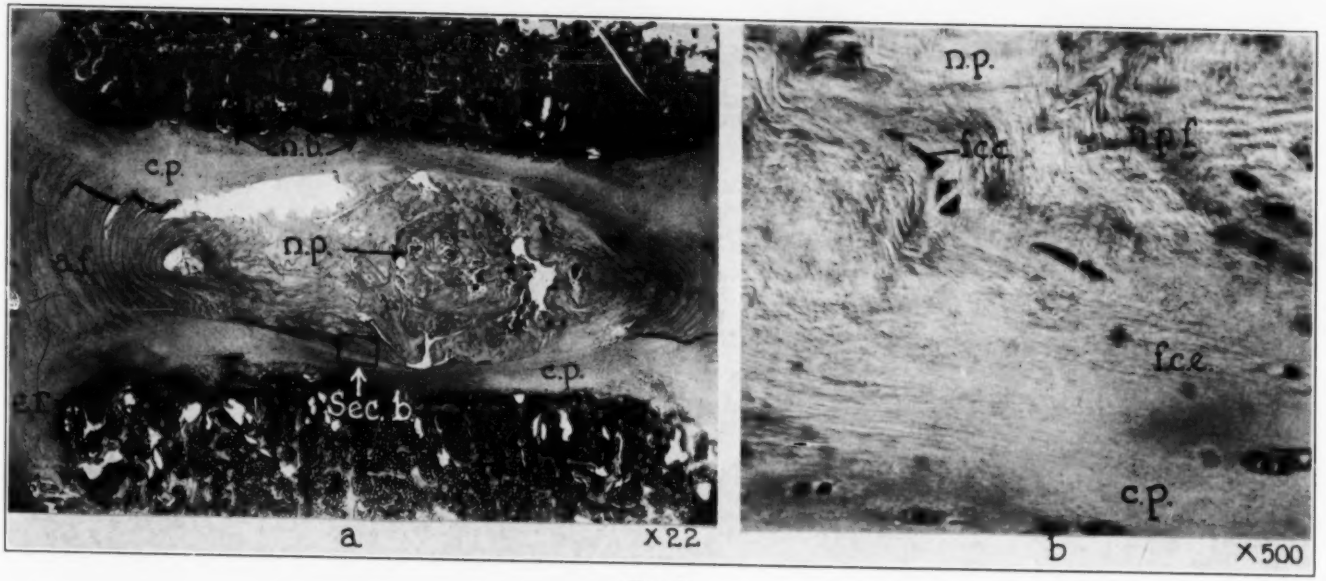

FIG. 8

From an eight-year-old child. (Three-fifths size of original illustration.)

a.f. annulus fibrosus; *n.p.* nucleus pulposus; *c.p.* cartilage plate; *e.r.* epiphyseal ring; *en.b.* enchondral bone formation; *f.c.e.* fibrocartilage envelope; *f.c.c.* fibrocartilage cells; *n.p.f.* nucleus pulposus fibers.

a. A mid-sagittal section through the first and second lumbar vertebrae and intervening disc. The enchondral bone formation extends across the entire bone end. The overlapping epiphyseal ring is better demarcated than in Fig. 7.

b. The hyaline and fibrocartilage portions of the cartilage plate and the fibrocartilage extensions into the nucleus pulposus are likewise better illustrated than in Fig. 7.

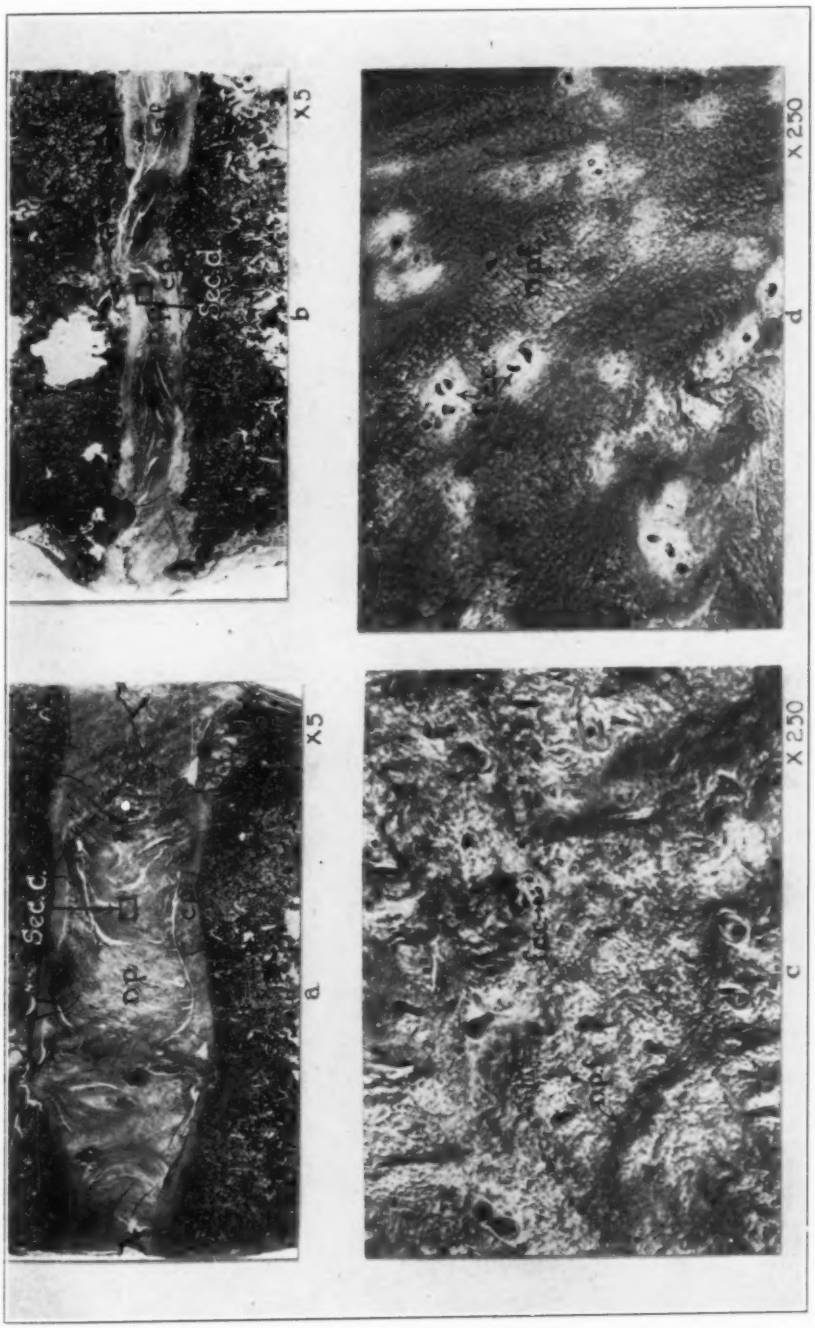

FIG. 9

Mid-sagittal sections through the intervertebral discs of a sixty-eight-year human adult. (One-half size of original illustrations.) Note the marked increase of the fibrous element at the expense of the mucoid matrix.
a.f. annulus fibrosus; *n.p.* nucleus pulposus; *c.p.* cartilage plate; *n.p.f.* nucleus pulposus fibers; *f.c.c.* fibrocartilage cells.

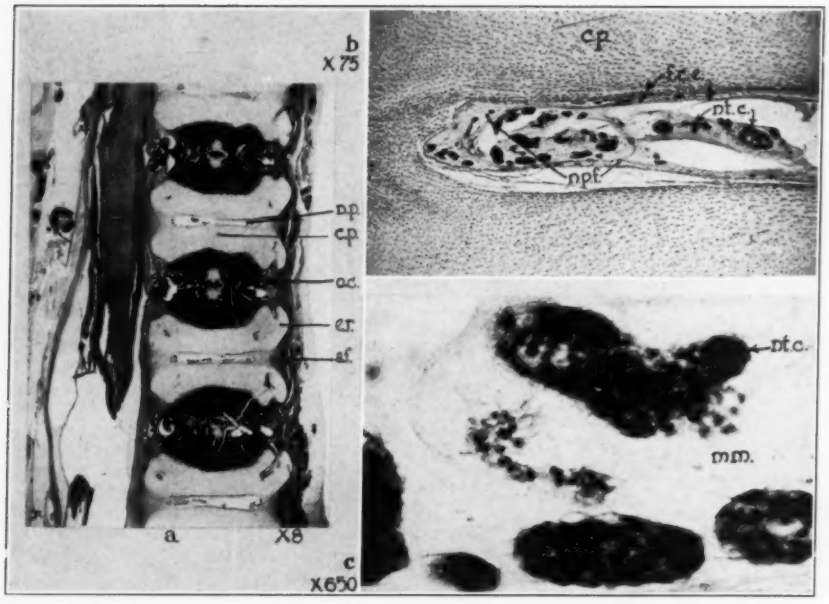

FIG. 10

A human embryo of two hundred millimeters (twenty-four weeks). (Two-fifths size of original illustration.)

n.p. nucleus pulposus; *a.f.* annulus fibrosus; *c.p.* cartilage plate; *o.c.* ossification center; *e.r.* epiphyseal ring; *n.p.f.* nucleus pulposus fibers; *nt.c.* notochord cells; *f.c.e.* fibrocartilage envelope; *m.m.* mucoid material forming matrix of nucleus pulposus.

a. A mid-sagittal section through the twelfth dorsal, first and second lumbar vertebrae. The ossification centers now separate the cartilaginous vertebral bodies into two cartilage plates covering the adjacent surfaces. The enchondral bone formation is seen to extend across the entire bone end.

b. and *c.* Are higher magnifications of the intervertebral disc and nucleus pulposus. They show the surrounding fibrocartilage envelope, expansions of which are invading the mucoid nucleus pulposus.

one intervertebral disc than could be found in the entire notochord of the embryo of seven and one-half weeks, in which mucoid degeneration was first noted. We feel, therefore, quite certain that, at least up to birth, the notochord tissue serves as the chief source of the nucleus pulposus material, and that the interspersed fibrous material and cartilage cells are derived from the fibrocartilage envelope. After birth the notochord cells disappear, though remnants may be found even in the adult nucleus pulposus. The growth of this body is now chiefly by proliferation of the

FIG. 11

The epiphyseal ring development. (Two-thirds size of original illustration.)

a.f. annulus fibrosus; *e.r.* epiphyseal ring; *en.b.* enchondral bone formation; *c.p.* cartilage plate; *cal.* calcification of cartilage plate; *b.t.* bone trabeculae; *b.m.* bone marrow.

a. A section through the epiphyseal ring region of a fifteen-year-old girl. Note the ossification center preceded by a zone of calcification obliterating the cartilage plate. This is quite comparable to the end stage of epiphyseal growth in any long bone.

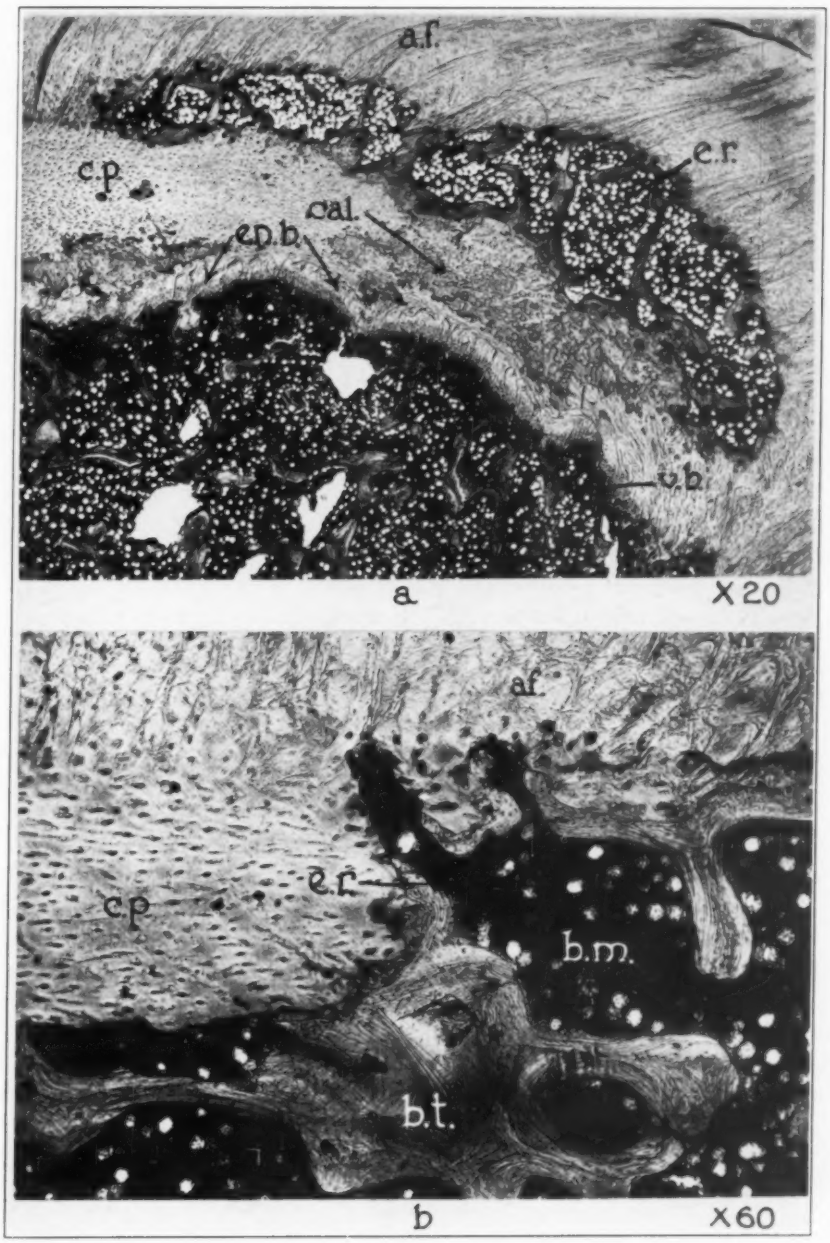

FIG. 11 (*Continued*)

b. A section through the epiphyseal ring region of a thirty-year-old woman. Note the complete fusion of the epiphyseal ring to the vertebral body. The cartilage plate does not fray out into the annulus fibrosus, but ends abruptly by abutting the bony epiphyseal ring. The annulus fibrosus fibers do attach to the cartilage plate, but only to the fibrocartilaginous part which was derived from the fibrocartilage envelope. Enchondral bone growth has disappeared both in the subepiphyseal ring and subcartilage plate regions.

fibrous element. These fibers may always be traced to their attachment to the fibrocartilage envelope, although this structure becomes intimately blended with the cartilage plate covering the adjacent surfaces of the vertebrae.

In the full-term foetus (Fig. 7) and fourteen-months-old child, fine strands of fibrocartilage are becoming more numerous in the mucoid nucleus pulposus. In the four-year-old child, the fibrous element is becoming quite prominent and frequent cartilage cells are encountered. Notochord cells are now difficult to find. In the eight-year and twelve-year discs (Fig. 8), the nucleus pulposus is made up almost completely of loose fibrocartilage with abundant gelatinous matrix. This process of maturation with fibrocartilage replacement of the gelatinous mucoid material progresses continually throughout life, until the senile intervertebral disc (Fig. 9) is composed almost entirely of a dense irregularly arranged fibrocartilage with an entire loss of its gelatinous character and resiliency. There has been noted independently by us and by Püschel [15], associated with Schmorl in Dresden, a progressive loss in water content of the intervertebral disc substance as age advances. Püschel reports that, in the full-term foetus, the water content of the nucleus pulposus is about eighty-eight per cent.; at eighteen years of age, this falls to eighty per cent.; and at seventy-seven years, to sixty-nine per cent. Our determinations compare very closely with these in that in the full-term foetus the water content of the nucleus pulposus was found to be eighty-eight per cent.; at twelve years, eighty per cent.; and at seventy-two years, seventy per cent.

In the embryo of twenty-four weeks (Fig. 10), the ossification center of the vertebral bodies divides the cartilaginous anlage of the vertebra into two separate plates covering the adjacent or intervertebral surfaces. It is from the central surfaces of these cartilaginous plates that osseous growth by enchondral bone formation is continued until full growth is obtained. This period is very variable and ends at between seventeen and twenty years of age in the female and at twenty to twenty-five years in the male. This cartilage plate is entirely comparable to the epiphysis of long bones (Fig. 11). On the surface of the cartilage plate adjacent to the osseous center is found a typical columnar arrangement of cells, calcification of the intervening matrix, and new bone formation. This process extends across the entire superior and inferior surfaces of the vertebral bodies and is not absent at the periphery in the region of the epiphyseal ring. At the periphery the cartilage plate overlaps the anterior and lateral borders of the osseous vertebrae. It is this portion of the cartilage plate that Schmorl and Beadle [16] attempt to separate as a peculiar and different structure, though obviously of the same genetic origin. In opposition to the views of Schmorl and Beadle, we believe that the only point of variance of this cartilage plate and any long bone epiphysis is that the final ossification (Fig. 11) does not extend completely across the bone end, but is confined to the peripheral portion, forming an incomplete bony ring

(epiphyseal ring). The remainder persists as the cartilage plate intimately blended with the fibrocartilage envelope previously described. It covers the bony vertebral surface, separating this from the nucleus pulposus, and gives attachment to the fibers of the nucleus pulposus and annulus fibrosus. The enchondral bone growth ceases simultaneously in the subcartilage plate region and in the subepiphyseal ring region when

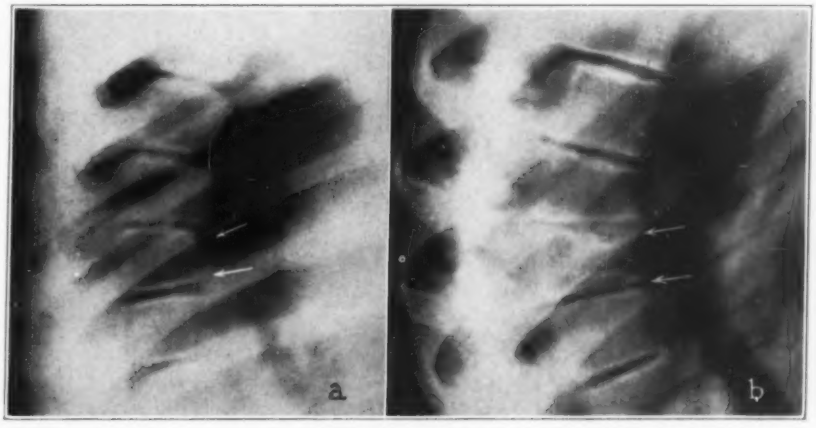

FIG. 12

a. A roentgenogram of the dorsal spine of an eight-year-old girl. Note the rarefaction about the epiphyseal ring region of the eighth dorsal vertebra.
b. A roentgenogram of the same region at the age of sixteen. Note the prolapse of the nucleus pulposus material into the adjacent vertebral bodies, the narrowing of the involved discs, and the marginal lipping and the round-back deformity.

bony union of the epiphyseal ring and vertebral body occurs. After fusion of the epiphyseal ring, the cartilage plate ends abruptly in the anterior and lateral regions by abutting this bony ring (Fig. 11). It does not fray out and become lost as Beadle would have us believe. The fraying out is merely the continuance of the annulus fibrosus and nucleus pulposus fibers into the fibrocartilaginous portion of the cartilage plate. Anteriorly and laterally the bony epiphysis serves this same function as the base of attachment of these fibers. As further evidence of the indivisibility of these two structures, we present the following case (Fig. 12):

A girl, eight years of age, was seen in 1924 with the complaint of backache, localized to the region of the eighth dorsal vertebra. An x-ray examination of this region revealed disturbance and rarefaction about the epiphyseal ring of the eighth dorsal vertebra. In 1932 roentgenograms were again taken of this patient, revealing a typical kyphosis dorsalis juvenilis with degeneration of the cartilage plate and prolapse of the nucleus pulposus material into the adjacent vertebral body. This involvement was also localized to the eighth dorsal vertebra. Thus disturbance of the cartilage plate was noted, first in the region of the epiphyseal ring and later in the cartilage plate proper.

Mau [17] also uses this type of case to refute Schmorl's theory that the epiphyseal ring exists as a structure unrelated to the cartilage plate.

THE ADULT INTERVERTEBRAL DISC

Because of the progressive changes throughout life occurring in the intervertebral disc, no normal can be accurately described unless the age be specified. It may be said here however that, in discs unaffected by pathological processes, the nucleus pulposus retains its semigelatinous consistency even beyond the fifth or sixth decade, and on sectioning the fresh specimen it is partially extruded by the elasticity of the annulus fibrosus.

We will describe as a normal intervertebral disc one in the third decade (Fig. 13). The adjacent vertebral surfaces are entirely covered by a thin layer of cortical bone. This is quite compact in the central area over the region of the nucleus pulposus, while peripherally it becomes more porous. The outer rim is raised and is the fused epiphyseal ring. Over this cortical bone lies the cartilage plate. This is composed of hyaline cartilage which ends abruptly in the anterior and lateral regions by abutting the bony epiphyseal ring. Intimately blended with this on its intervertebral surface is a layer of fibrocartilage which gives attachment to the fibers of the annulus fibrosus and nucleus pulposus. The annulus fibrosus is a dense fibrocartilage, firmly attached to the adjacent vertebrae, and forming a strong but elastic envelope of the fibrogelatinous, incompressible nucleus pulposus. The adult intervertebral disc contains neither blood vessels nor nerves. The nutrition of this body is carried entirely by the lymph stream. Jung and Brunschwig [18], after careful study, found nerve fibers only in the anterior and lateral longitudinal ligaments.

THE FUNCTION OF THE INTERVERTEBRAL DISC

The nucleus pulposus is a fibrogelatinous material subject to the laws of fluids. It may be considered, therefore, incompressible and confined to its normal shape and position by the strong and elastic annulus fibrosus. It is the elastic tension of the latter which extrudes the nucleus pulposus material when the disc is sectioned. The pressure of the nucleus pulposus material in the living organism is not only the result of the elastic tension of the annulus fibrosus, but also that of muscle tone and static forces transmitted from one vertebral body to the next. The proper function of the nucleus pulposus, therefore, depends upon the integrity of its limiting structures, *viz.*, the cartilage plates above and below and the surrounding annulus fibrosus. The primary hypothesis of incompressibility of the nucleus pulposus demands that any compression of the intervertebral disc must result from the change of shape of the nucleus pulposus at the expense of the elastic annulus fibrosus. The amount of compression of the intervertebral disc will, therefore, depend upon the elasticity and strength of this structure. From observation of this fibrocartilaginous ring, we may postulate that only minor changes may take place under the forces to which it is exposed. These changes, however, are sufficient to give the intervertebral disc enough resiliency to absorb the

shocks transmitted along the vertebral column. The incompressibility of this portion of the intervertebral disc lends to it the function of transmitting the static and muscular forces from one vertebral body to the next and establishes it as the axis of motion upon which each vertebral body must work (Fig. 14).

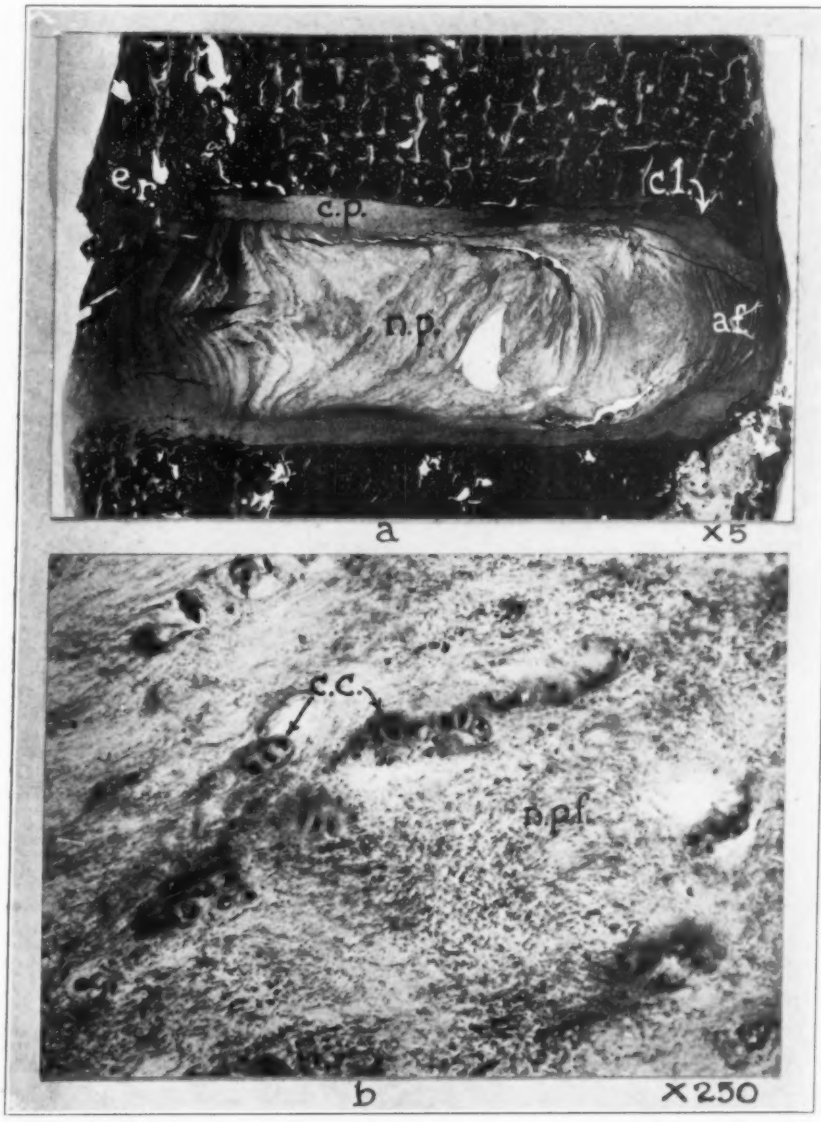

FIG. 13

A normal intervertebral disc in a twenty-four-year-old woman (first lumbar). (Two-thirds size of original illustration.)

a.f. annulus fibrosus; *n.p.* nucleus pulposus; *c.p.* cartilage plate; *c.l.* cortical layer of bone covering the adjacent surfaces of the vertebral bodies; *e.r.* epiphyseal ring; *c.c.* cartilage cells; *n.p.f.* nucleus pulposus fibers.

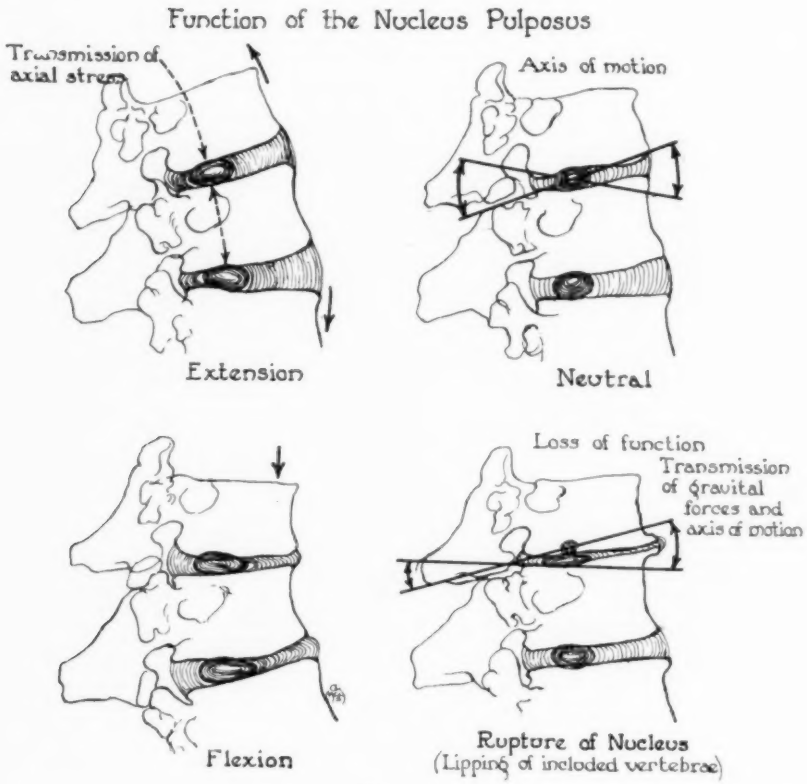

FIG. 14

A diagrammatic sketch illustrating the function of the intervertebral disc.

PATHOLOGY OF THE INTERVERTEBRAL DISC

The pathological physiology of the intervertebral disc can be best understood if one keeps constantly in mind the fact that the nucleus pulposus is the medium of transmitting pressure from one vertebra to the next. On the surface of each disc a pressure force is exerted on the concave side and a depression force on the convex side. These forces counterbalance each other, but the force of gravity persists on the nucleus which represents the transmission of the weight from one vertebra to the next by the intermediary of the nuclear axis. Any pathological process which weakens the structures confining the nucleus pulposus, invades the nucleus itself, or merely allows portions of the nuclear material to escape, will greatly interfere with the normal function of the spine.

Symptoms, characterized by pain in the back and disability, may not be expected in the spine with minute ruptures of the cartilage plate and small extrusions of the nuclear material. Schmorl [4] concluded from his studies that the nuclear prolapses which he found in thirty-eight per cent. of the spines which he studied at autopsy were of little clinical significance, but he reviewed the histories of only five of the patients upon whom

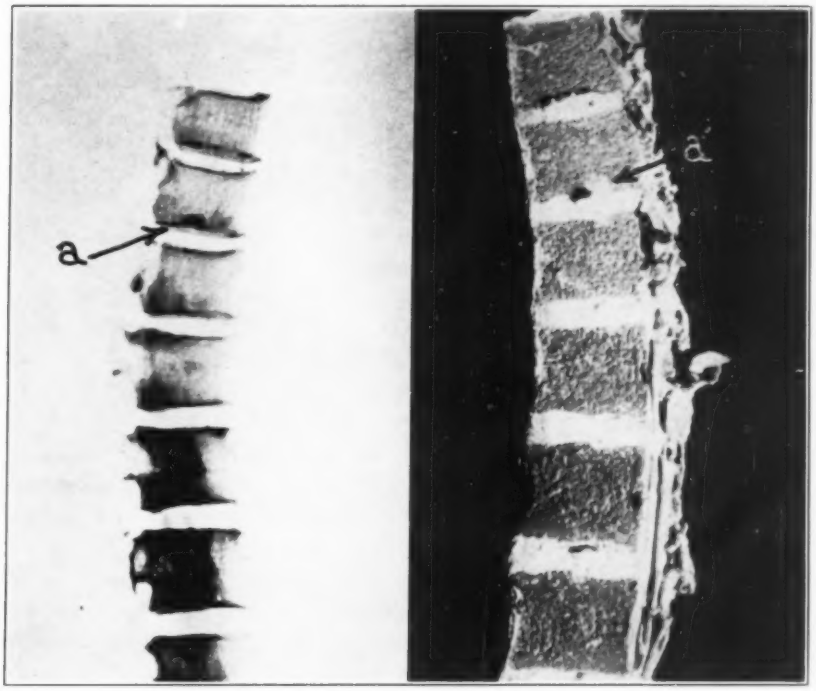

FIG. 15

Several ruptures of the nuclei pulposi are noted in the gross specimen, but only the large prolapse (a') can be recognized in the roentgenogram.

autopsies were performed in his institute. Beadle [16] suggested the course of the pathological processes in a number of clinical conditions affecting the spine, but the part played by the nucleus pulposus lesions themselves has not been satisfactorily defined.

Jung and Brunschwig [18] have recently studied the innervation of the articulations of the vertebral bodies and have demonstrated sensory nerves in the anterior longitudinal ligament, but no nerve fibers of any kind were found in the intervertebral disc. For this reason trauma or disease affecting the intervertebral disc can produce subjective symptoms only in proportion to the degree in which the adjacent structures are involved.

The commonest lesion of the spine, according to Schmorl, and confirmed by our observations, is the prolapse of the nucleus pulposus into the spongiosa of the vertebral body. The mere presence of these cartilaginous nodules may not cause pain in the back. The nuclear material is extruded through a crack or other defect in the cartilage plate into the spongy bone by the force which is transmitted to that disc by the weight of the body and by the tone of the spinal muscles and ligaments. As a result of this invasion, a reaction is set up in the bone. The semifluid material is transformed into a cartilage nodule and the bone about it becomes sclerosed, forming a secondary line of defense to wall off the invad-

ing material (Fig. 15). This sclerosed bone about the nodule may be noted in the roentgenogram, but, until sufficient time has elapsed following the prolapse of the nuclear material of the disc for the reaction in the bone to take place, the roentgenological diagnosis usually cannot be made.

If only a small portion of the nucleus pulposus is extruded, the function of the intervertebral disc may not be seriously affected, and no immediate disability would be expected. The extrusion, however, of even minute portions of the semigelatinous nucleus pulposus may open avenues for dehydration of the disc and hence diminished function at an earlier age than such changes normally occur. This has been shown by the studies of Püschel and has been confirmed by us. We believe that such small ruptures may thus be a predisposing etiological factor in the development of arthritis of the spine years later.

If a considerable portion of the semifluid material escapes either into the spongy bone or through the fibers of the annulus fibrosus, the weight of the body and the trauma of every-day life can no longer be transmitted from one vertebral body to the next through this semifluid cushion, but must be borne in part by the fibrocartilaginous annulus fibrosus. The intervertebral disc then becomes thinner and in some instances completely wears out. When the nucleus pulposus has been destroyed, the axis of motion is shifted posteriorly to the articular facets and the weight

FIG. 16

This section was taken from the spine of a patient, aged forty-six years. There is a prolapse of nucleus pulposus material (*p.n.p.*) with subsequent narrowing of the intervertebral disc (*iv.d.*). Osteo-arthritis, with lipping (*a*) at the anterior edges of the vertebral bodies and beginning ossification of the anterior longitudinal ligament, has followed the diminished function of the nucleus pulposus. (Two-thirds size.)

of the body, especially in all forward or lateral bending, is transferred to the lateral or anterior portion of the vertebral bodies themselves. As a result of this the adjacent vertebrae may become sclerosed and the lipping and spurs characteristic of osteo-arthritis of the spine will be noted (Fig. 16). If the vertebral body has been softened by disease, such as tuberculosis or neoplasm, it may be eroded and ultimately completely destroyed.

Fifty-nine years before Schmorl engaged the interest of pathologists in the nucleus prolapses noted upon section of the spine at autopsy, Virchow,[8] in 1857, described a tumor found upon the inner surface of the base of the skull, and, believing it to be a growth of cartilage, named it "ecchondrosis physalifora." Müller[19], tried to show that this tumor was derived from notochordal tissue, and Steiner[20], in 1894, after a careful study of a similar case, concluded that Müller was correct in this hypothesis. Their interest did not lead to further studies of the nucleus pulposus.

Calvé and Galland[21], in 1922, and Bársony and Polgár[22], in 1925, described calcification of the nucleus pulposus. Schmorl, in 1927, reported that thirty-eight per cent. of the spines which he routinely sectioned at autopsy showed prolapses of disc material into the spongiosa of adjacent vertebral bodies. He attributed little clinical significance to these findings, but Schanz[23] suggested the possibility of a direct causal relationship between these prolapses or cartilage nodes and backache. Mau[17] and Müller[24], in 1928, and Dittrich[25], in 1929, found evidence of nuclear prolapses characterized by sclerosis about punched-out areas in the vertebral bodies, as seen in the lateral roentgenograms of cases in which there was a history of pain in the back and disability.

Andrae[26] and Schmorl[4] described prolapses of the nucleus pulposus posteriorly with extension of the disc into the spinal canal and Calvé and Galland[21] reported two clinical cases in which a diagnosis of this condition was made. Many additional articles reporting single cases of lesions of the intervertebral disc, or autopsy findings, have appeared in the journals of the last three years, mostly in the German literature, while Geist[27] and Sashin[28], as well as Calvé and Galland, have reviewed the work of Schmorl in American journals and have postulated regarding the clinical significance of the changes in the intervertebral nucleus pulposus.

In a very complete recapitulation of the entire subject of the intervertebral discs, Beadle[16] has discussed their normal and morbid anatomy in relation to certain spinal deformity.

Geist[27], Calvé and Galland[21], Sashin[28], and Beadle[16] have enumerated a number of pathological conditions in which the intervertebral nucleus pulposus is either primarily or secondarily involved. We have elected to classify the various lesions according to the primary location of the pathological process. It is obvious that there must be some overlapping in the three groups, but the following grouping has been suggested: (1) pathological conditions of the nucleus pulposus; (2) pathological conditions of the cartilage plate, and (3) pathological conditions in the vertebral bodies.

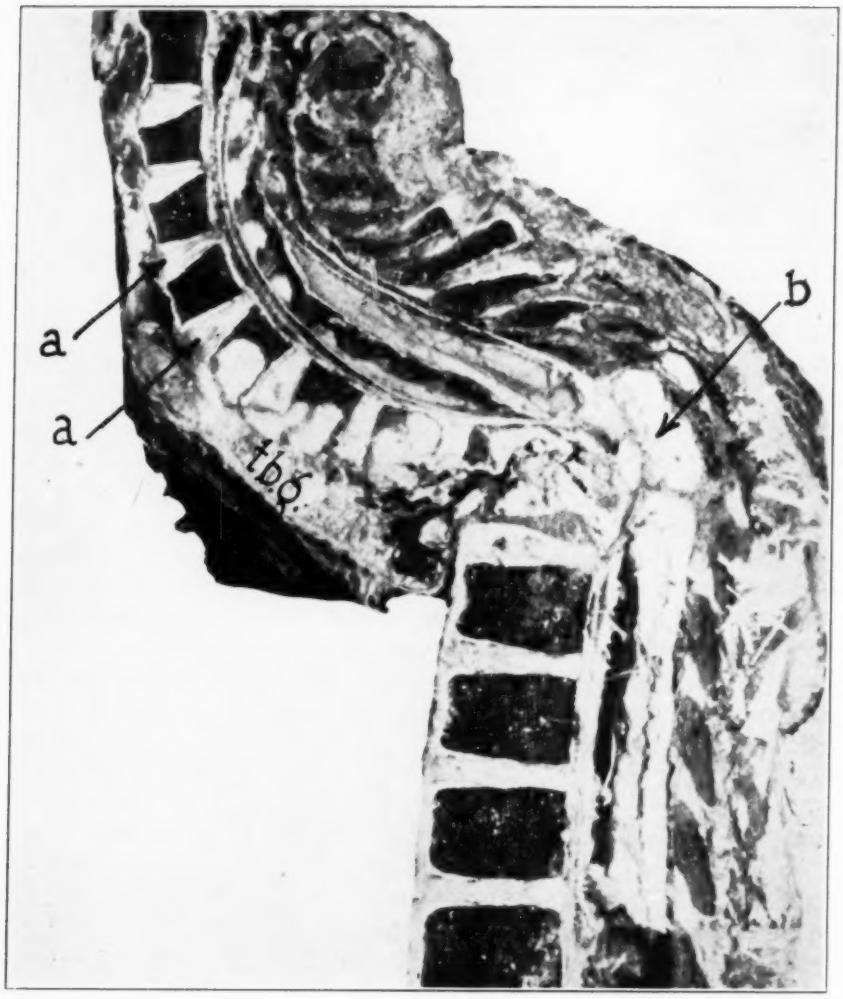

FIG. 17

The pathology of tuberculosis of the spine is demonstrated in this gross specimen. Several vertebral bodies have been destroyed and the spinal cord has been crushed at the apex of the kyphos (*b*). The hyperextension of the spine above and below the marked kyphos has resulted in a forward shift of the nucleus pulposus (*a*). Tuberculous granulation tissue (*tb.g.*) is extending upward along the vertebral bodies under the anterior longitudinal ligaments.

PATHOLOGICAL CONDITIONS OF THE NUCLEUS PULPOSUS

1. *Retropulsion or Antepulsion of the Nucleus Pulposus.* Calvé and Galland described kyphosis with nuclear retropulsion in which there was paraplegia from pressure of the bulging intervertebral disc against the spinal cord. Two similar cases were reported by Dandy [29] in 1929 and still another by Bucy [30] in 1930, but the possible rôle of the nucleus pulposus was not suggested by either author. A forward shift of the nucleus

has been noted in an attempt to compensate for the kyphos in tuberculosis of the spine (Fig. 17).

2. *Lateral Shift of the Nucleus Pulposus.* In scoliosis of the spine the nucleus pulposus has been found shifted to the side of the convexity of the curvature and, while Schmorl was not able to find evidence that this was in any way an etiological factor in the production of scoliosis, this shift of the non-compressible nucleus may be the explanation of much of the difficulty found in attempts to correct the lateral curvature.

3. *Calcification of the Nucleus Pulposus.* This condition has been described by a number of authors including Calvé and Galland, Bársony and Polgár [22], Breton [31], Lyon [32], and Dittrich [25], while Schmorl studied the condition anatomically and pathologically. This usually occurs in elderly patients in whom the diagnosis of Pott's disease may have been made. Microscopically the calcification is seen *particularly* in the shape of fine grains between the fine fibrous network of the nucleus, and in the shape of larger blocks friable in character. The cells of the nucleus are necrosed and the fibrous tissue is destroyed by the calcareous deposit (Fig. 27, Case 9).

4. *Dehydration of the Nucleus Pulposus.* With the advance of age, the percentage of water content of the nucleus pulposus becomes less and its efficiency is accordingly decreased. This dehydration phenomenon may be greatly accelerated by the production of small ruptures in the cartilage plate with the loss of portions of the nucleus pulposus material which may be microscopic in size. These degenerative changes decrease the efficiency of the spine and lead to the development of osteo-arthritis.

PATHOLOGICAL CONDITIONS OF THE CARTILAGE PLATE

The cartilage plate confines the nucleus pulposus above and below, and overlies a very thin layer of cortical bone. The two structures together are called upon to withstand the pressure exerted through the nucleus pulposus upon the vertebral body itself.

1. *Prolapse of the nucleus pulposus as a result of congenital defect* in the cartilage plate has been suggested by Schmorl. As has been demonstrated in the embryological studies, the notochordal substance is squeezed from the vertebral body by the rapidly growing cartilage cells. Occasionally notochordal tissue has been described in the vertebrae of adults and this, together with the occasional discovery by Schmorl of prolapses of the nucleus pulposus material into many of the vertebral bodies of a relatively young individual, and at about the site from which the notochord was extruded, has led to the theory that there may have persisted at this point a defect in the cartilage plate through which the prolapses occurred. The flaw in the theory lies in the fact that such a defect has not been demonstrated in the foetal spine. Such defects with early prolapses may be suggested as an additional etiological factor in the production of the so called *epiphysitis dorsalis juvenilis.*

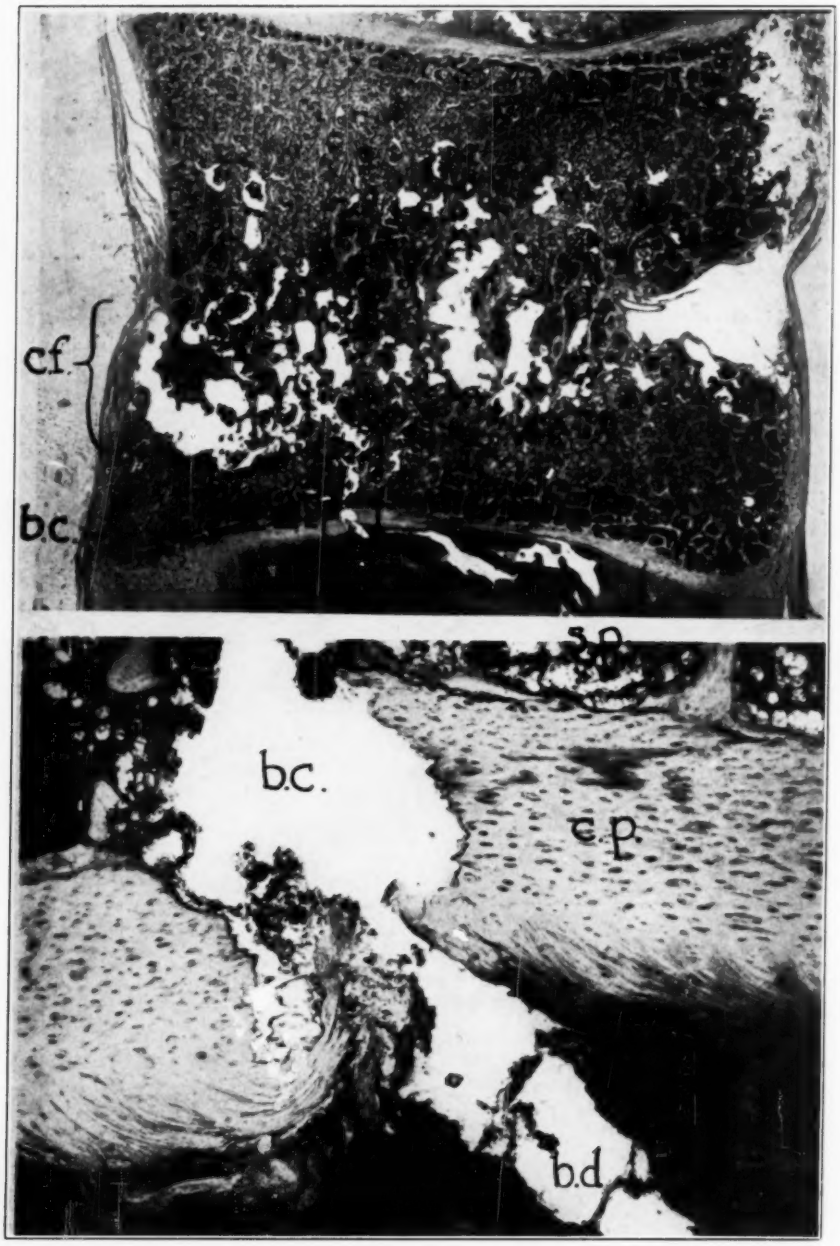

FIG. 18

The vertebral body was badly crushed (*c.f.*) when the patient jumped from a fifth story window, but only one break (*b.c.*) in continuity of the cartilage plate was found. The higher magnification shows the break (*b.c.*) in the cartilage plate (*c.p.*) and the extension of the defect into the intervertebral disc (*b.d.*) and the spongy cancellous bone (*s.p.*).

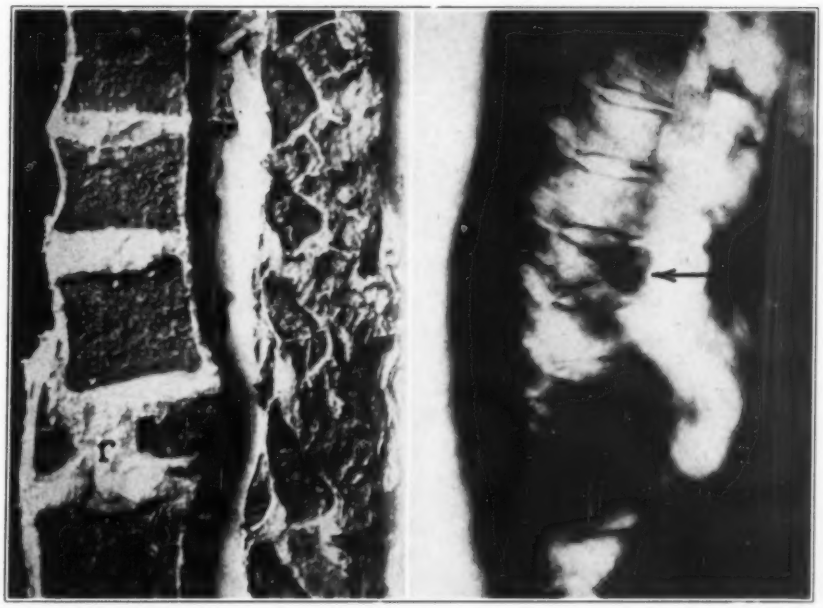

FIG. 19

The gross specimen, taken from Schmorl, illustrates the production of a cartilage mass (*r*) which has separated the anterior and posterior halves of the fractured vertebral body, preventing union. The x-ray shows a similar condition in a patient followed in this clinic. X-rays taken one year before, shortly after the injury, were reported "no gross pathology".

2. *Injury of the cartilage plate as a result of chronic trauma* has been suggested by Schmorl as the predisposing factor in most of the prolapses of the nucleus pulposus. These cartilage nodules were found most frequently in the spines of individuals who had been active in athletics or who had engaged in hard labor.

3. *Injury of the cartilage plate as a result of acute trauma* is often associated with *fracture of the vertebral body.* The cartilage plate is surprisingly strong and may not be opened even though a force sufficient to produce a fracture of the vertebra is exerted upon it. In a spine which we obtained from an adult male who committed suicide by jumping from a fifth story window, we found two vertebral bodies crushed, but there was only a small crack in the cartilage plate of the intervertebral disc between them (Fig. 18). In other instances, however, roentgenograms have not revealed any lesion of the vertebrae following an injury, but months or years later, when symptoms of backache have persisted, roentgenological studies have shown separation of anterior and posterior halves of a vertebral body or marked collapse of the vertebral body with narrowing of one or both intervertebral spaces adjacent to it. *Kümmel's kyphosis* may be due to injury of the cartilage plate upon both sides of the vertebral body with subsequent extrusion of the nucleus pulposus from each disc until the vertebra itself has been completely divided by a cartilage nodule (Fig. 19).

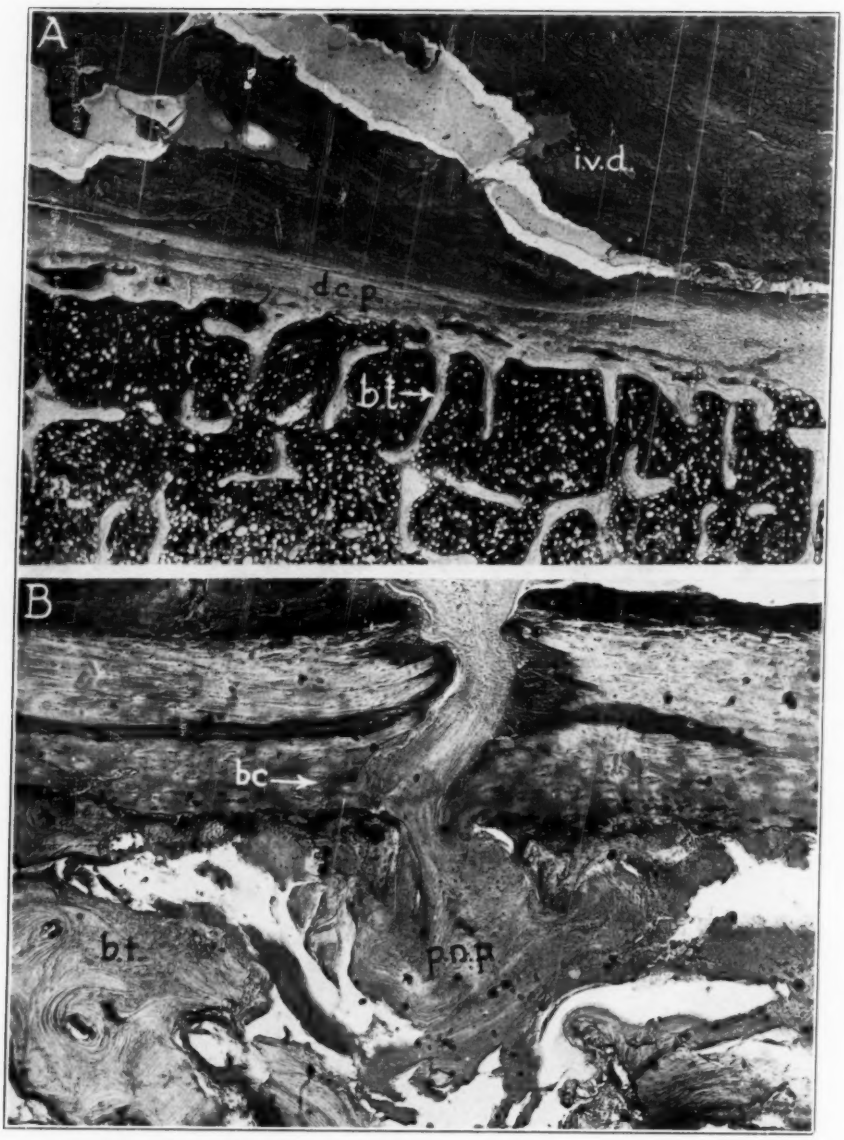

FIG. 20

Fibrillation of the cartilage plate (*d.c.p.*) is demonstrated in *A*. In *B* the plate has ruptured and nucleus pulposus material (*p.n.p.*) of the intervertebral disc (*i.v.d.*) is streaming through. The bone trabeculae in this section have become much enlarged. A cartilage nodule (*p.n.p.*) has been formed in *C* and a zone of sclerosed bone (*s.b.*) is noted about it. (Two-thirds size.)

The disturbance of circulation in the bone together with the wear and tear resulting from the loss of the two cushions or shock-absorbing effect of the nuclei pulposi might easily explain the subsequent necrosis of the bone.

4. *The fibrillation of the cartilage plate* has been described by Schmorl and has been repeatedly demonstrated in the spines which we have studied.

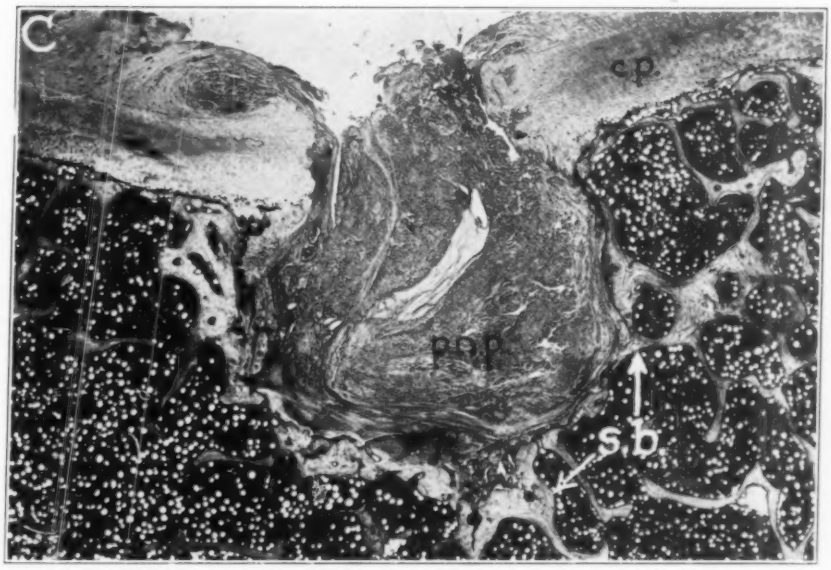

FIG. 20 (*Continued*)

It is analogous to the fibrillation in the cartilage of the knee or of the hip which is characteristic of *degenerative or osteo-arthritis* of those joints and is probably merely a result of wear and tear (Fig. 20). The loss of nucleus pulposus material through these splits in the cartilage, together with the gradual dehydration of the nucleus material, greatly lessens the resiliency and efficiency of the intervertebral disc. This leads also to narrowing of the disc, increased stress and strain upon the vertebral bodies themselves, and is followed by sclerosis, lipping, and spur formation. We are convinced from our studies that this is one of the etiological factors in the development of degenerative or osteo-arthritis of the spine.

5. *Disease processes affecting the cartilage plate.* Acute *pyogenic infections of the spine* may attack the cartilage plate and secondarily destroy the intervertebral disc itself. *Tuberculosis of the spine* is sometimes first suspected roentgenographically because of narrowing of the intervertebral space. In our pathological studies we have found sections in which tuberculous granulations were undermining and destroying the cartilage plates (Fig. 21). With the destruction of the cartilage plate, the function of the nucleus pulposus is lost and the tissue itself is extruded into the diseased vertebral body.

PATHOLOGICAL CONDITIONS IN THE VERTEBRAL BODIES

1. This includes conditions in which *the nucleus pulposus is not destroyed* but the vertebrae themselves are no longer able to stand the pressure exerted upon them. This is seen in cases of softening of the bones as in *osteomalacia, generalized osteitis fibrosa,* or *senile osteoporosis*

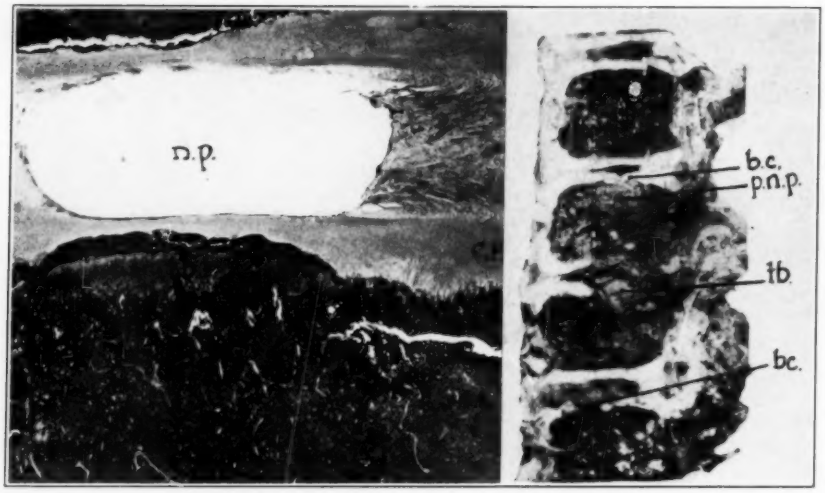

FIG. 21

Tuberculous granulation tissue (*t.b.*) has extended along the plane between the cartilage plate (*C.P.*) and the cancellous bone and the cartilage has been eroded and thinned out. In the gross specimen the tuberculous granulations have penetrated the cartilage plates (*b.c.*) and invaded the intervertebral discs. The nucleus pulposus material (*p.n.p.*) has prolapsed into the diseased vertebrae. (One-half size.)

(Fig. 22). The vertebrae may become biconcave, similar to the vertebrae of a fish, while the discs become spherical. The cartilage plates usually remain intact but they may become so thinned out as a result of the stretching that they will burst, with subsequent prolapse of the nucleus material into the adjacent vertebral body.

2. *Benign or malignant neoplasms may invade* the vertebrae and so weaken them that the nucleus pulposus will prolapse into the softened bone. The malignant neoplasms may be primary or metastatic. The lesions of this type which we have studied include: *endothelioma, multiple myeloma, sarcoma,* and *carcinoma.*

For more than two years we have sought roentgenological explanations in all cases in which there has been complaint of pain in the back and disability, or of spinal deformities. We have, whenever permitted to do so, sectioned the spine at autopsy and have studied the gross lesions microscopically.

No attempt will be made in this brief discussion to include a complete report of clinical cases. The following are merely a few which have been diagnosed as nucleus pulposus disturbances, and are included to illustrate the methods of diagnosis and our plan of treatment.

CASE REPORTS

CASE 1. *Kyphosis.* Wm. T., male, aged forty-two. Complained of severe back pain dating from an injury five years previously when he fell from a truck. This pain had become more marked until he was completely disabled. Examination revealed a rounded

kyphos of the dorsal spine. X-rays showed narrowing of the intervertebral space with sclerosis and lipping of the anterior portion of the vertebral bodies and many punched-out, sclerosed areas (Fig. 23). No foci of infection were found. Heat and massage and salicylates afforded no relief but he was immediately relieved by a properly fitted back brace. As this man had to earn his living by physical labor he objected to the inconvenience of the brace, but could not work at all without it. Using a very long, full-thickness graft from the tibia, the spine was fused, February 24, 1932. He has been completely relieved by this internal splint and has been working again for several weeks.

Case 2. *Epiphysitis Dorsalis Juvenilis.* H. P., female, aged eighteen years. Patient came complaining of severe dorsal backache and moderate dorsum rotundum of two years' duration. There was no definite history of injury, although she had fallen from riding horses a number of times. X-rays revealed numerous punched-out areas in the vertebrae with narrowing of the intervertebral space. She was relieved by wearing a back brace (Fig. 24).

Case 3. *Prolapse of Nucleus Pulposus Following Acute Trauma.* L. D., aged seventeen years, patient of Dr. Steindler. Complained of pain and a feeling of crunching in the upper lumbar region whenever he resumed the erect position after stooping over. Four years previously, during a wrestling match, his back had been bent sharply over his

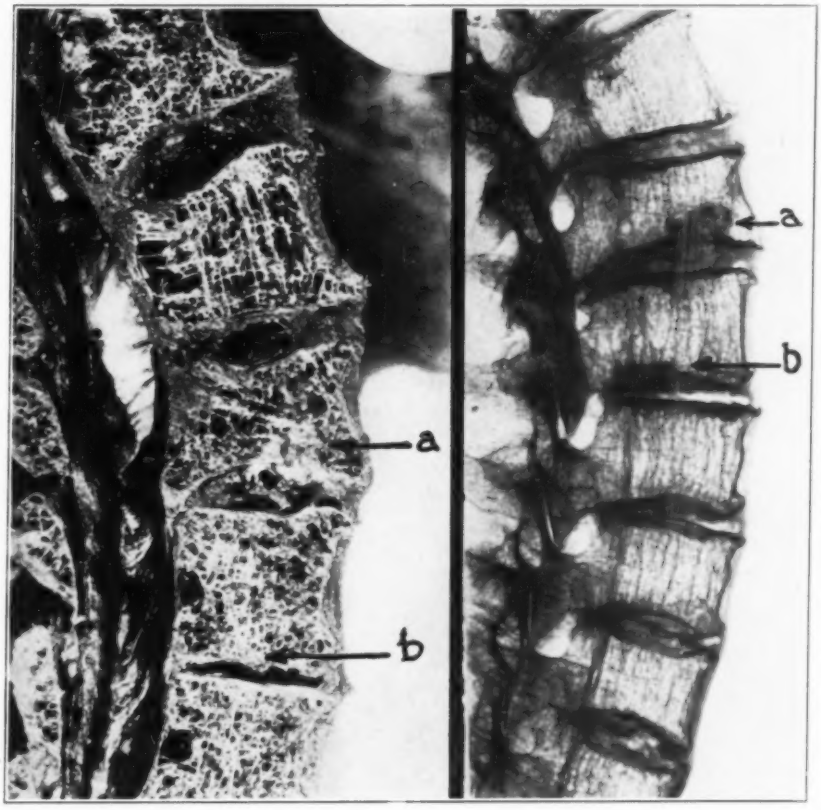

Fig. 22

This museum specimen demonstrates the biconcave, osteoporotic vertebrae with several ruptures of the nuclei pulposi, two of which (*a* and *b*) can be identified in the x-ray.

opponent's knee. Pain and weakness in the back lasted for two weeks. Similar attacks of pain recurred intermittently for the next four years and for the past four months it had been continuous. An x-ray revealed definite narrowing of the intervertebral space between the first and second lumbar vertebrae and a sclerosed, punched-out area in the body of the second lumbar vertebra. He is wearing a back brace with complete relief of symptoms, but, if he attempts to discard the back brace, the symptoms immediately return.

CASE 4. *Nucleus Prolapses Associated with Scoliosis.* Mary P., aged sixteen years, was followed in Dr. Steindler's clinic for eleven years because of congenital club feet. The spine was found to be normal at each of several physical examinations. In the eleventh year a slight scoliosis was noted, although there were no subjective symptoms. One year later the patient began to complain of intermittent, dull aching pains, located in the lower back, gradual in onset and progressive in nature, and aggravated by exercise. X-rays showed the typical punched-out areas suggestive of nucleus pulposus prolapse in several of the lumbar vertebrae. She was completely relieved of symptoms by a back brace.

CASE 5. *Osteoporosis of the Spine.* M. Mc., aged fifty years, came to the University

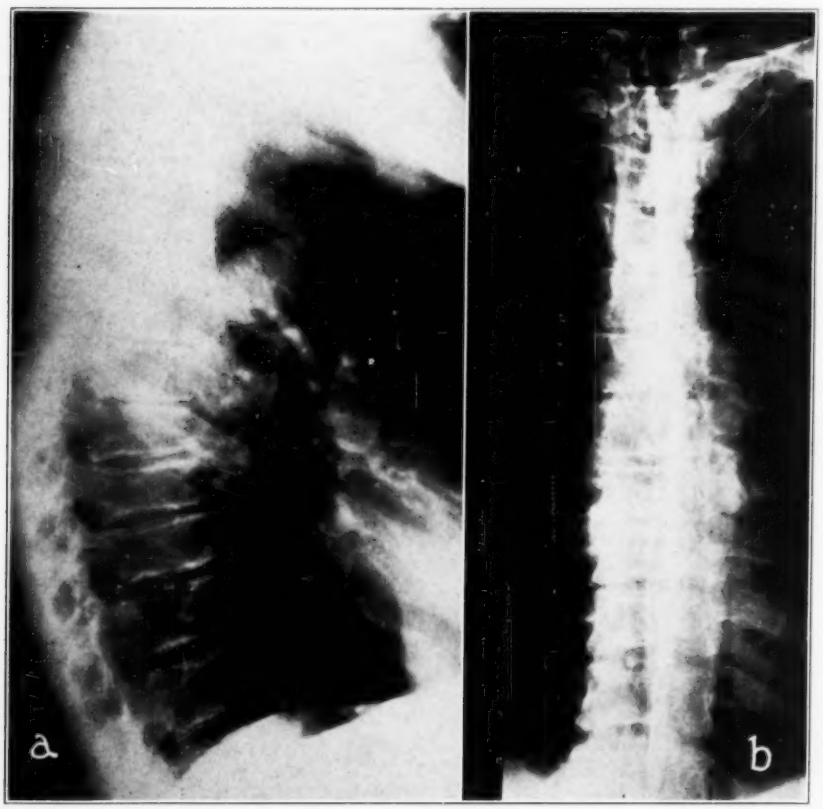

FIG. 23

Case 1. The lateral roentgenogram (*a*) shows the rounded kyphos, narrow intervertebral spaces with sclerosis and lipping of the anterior portion of the vertebral bodies and many punched-out areas, suggesting ruptures of the nuclei pulposi into the spongy cancellous bone. The anterior-posterior view (*b*) shows the bone graft which extends from the second to the twelfth dorsal vertebrae and effectively splints the spine.

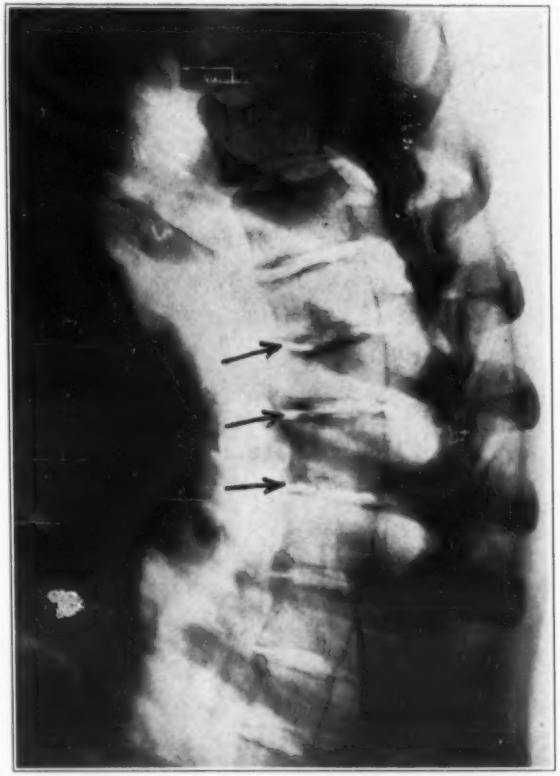

FIG. 24

Case 2. Note the irregularity of the adjacent surfaces of the vertebrae with narrowing of the intervertebral spaces.

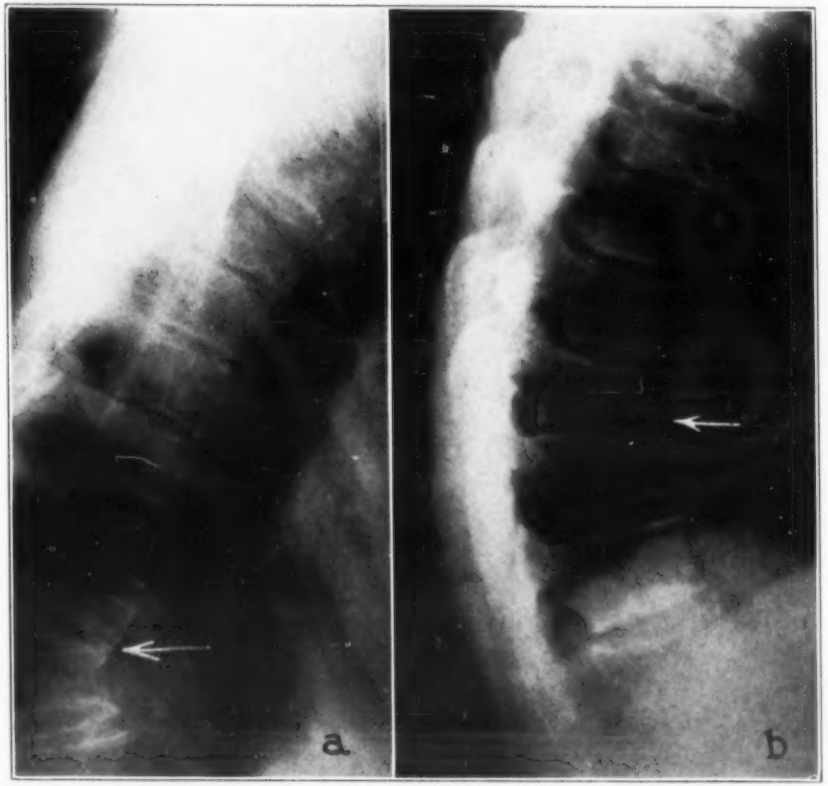

FIG. 25

Case 6. The roentgenograms show the compression fracture of the vertebral body with kyphosis of the spine, narrowing of the adjacent intervertebral spaces, and lipping of the vertebral bodies anteriorly.

FIG. 26

Case 7. The extensive destruction of vertebral bodies by tuberculosis is illustrated both in the roentgenogram and the photomicrograph. The cartilage plate (*C.P.*) has been broken through and the nucleus pulposus (*N.P.*) has prolapsed (*P.N.P.*) into the diseased vertebral body (*Vb.*). (Two-thirds size.)

of Chicago Clinics because of pain and weakness in the dorsal and lumbar spine. The back was rounded and patient had decreased about two inches in height during the year. X-rays showed biconcave, fish-shaped osteoporotic vertebrae, with many ruptures of nuclei pulposi. She has been partially relieved by a back brace.

CASE 6. *Compression Fracture of the Spine.* A. C., aged forty-eight years, came to us complaining of difficulty in walking, associated with severe pain in the back and both legs, following a fall of thirty feet three years before. Examination revealed a marked dorsolumbar kyphos, marked limitation of the spine in all of its movements, and partial paralysis in both lower extremities. The roentgenograms revealed compression fractures of the tenth dorsal and the first lumbar vertebrae and punched-out areas in several other vertebrae. The spine was hyperextended and then fused September 18, 1930, from the eighth dorsal to the fourth lumbar vertebrae by means of two full-thickness, tibial bone grafts. The pain has been completely relieved and the patient has been able to work for the past eight months (Fig. 25).

CASE 7. *Tuberculosis of the Spine.* C. C., aged thirteen years. This patient had complained of pain in the back for six years and she had been treated for tuberculosis of the lumbar spine by means of casts and rest in bed until coming to our clinic. X-rays showed tuberculosis of the second, third, and fourth lumbar vertebrae with loss of the intervening intervertebral discs. The patient died of tuberculous meningitis one month after fusion of the spine, and the diseased portion of the spine was removed at autopsy. This revealed destruction of the intervertebral discs with extension of the nucleus pulposus material into the vertebral bodies (Fig. 26).

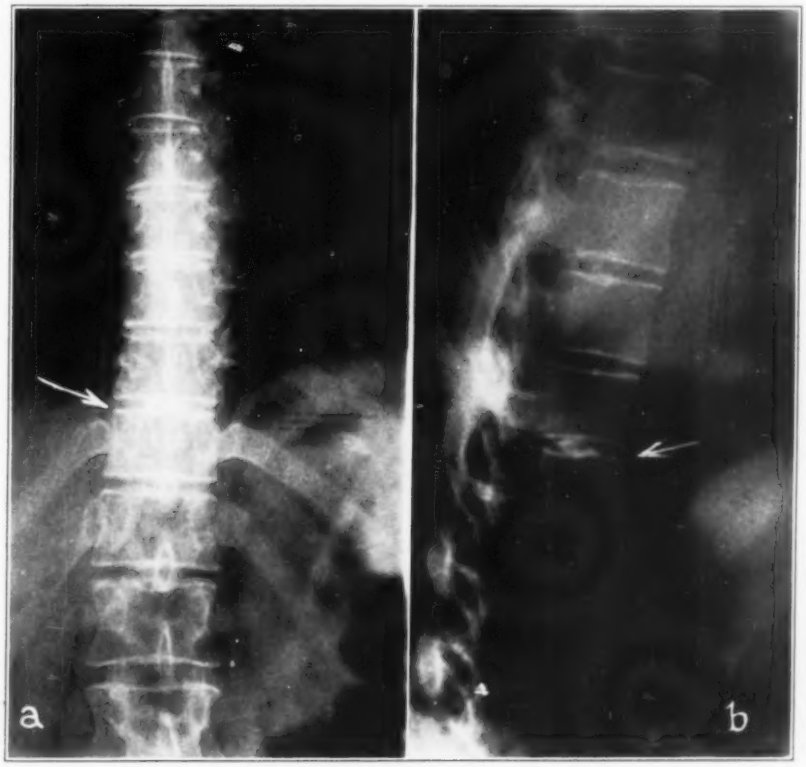

FIG. 27

Case 9. The calcified nucleus pulposus is clearly visualized in both the lateral and the anterior-posterior views.

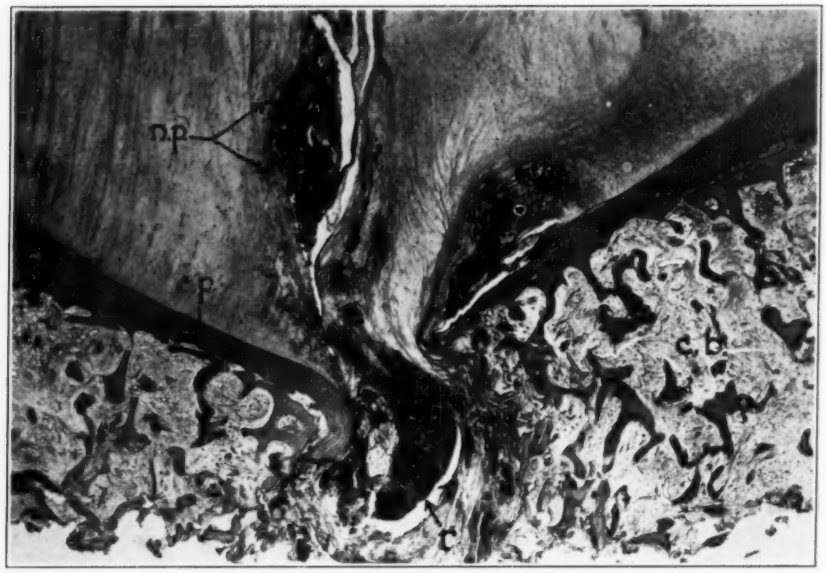

FIG. 28

Case 10. The softened vertebral body has been depressed until the cartilage plate (*c.p.*) has become thinned out and finally ruptured. The nucleus pulposus material (*n.p.*), still containing many pigmented-cell nuclei, is streaming through the defect and forming a node (*r*) in the cancellous bone. (Two-thirds size.)

CASE 8. *Charcot's Disease.* A. A., male, aged forty-three years. Complained of pain in the lower back for one week only. X-rays showed erosion or crushing of the third, fourth, and fifth lumbar vertebrae with marked narrowing of the intervertebral discs. These vertebrae showed marked evidence of bone proliferation with sclerosis and marginal lipping. He was markedly relieved by back brace.

CASE 9. *Calcification of the Nucleus Pulposus.* E. L., female, aged forty years. (Bone and Joint Service of University of Michigan.) Complained of pain in the lower dorsal region of the spine penetrating through to the abdomen, worse in the morning and during activity. Examination revealed a full range of motion in the spine without any muscle spasm. X-rays revealed a calcified mass in the intervertebral disc between the tenth and eleventh dorsal vertebrae. This was confined to the portion of the disc just posterior to the middle third, which is typically occupied by the nucleus pulposus. She has been somewhat relieved by wearing a corset (Fig. 27).

CASE 10. *Carcinoma Metastases to the Spine.* B. O'N., aged thirty-one years. Patient was first seen January 24, 1930, when a diagnosis of inoperable carcinoma of the uterus was made. The diagnosis was proved by biopsy. She was treated vigorously with x-ray and radium. In April, 1930, she first complained of backache. This pain persisted until her death from the carcinoma in April, 1931. The portion of the spine in which she had complained of back pain was removed at autopsy. A relatively recent rupture of the cartilage plate with extrusion of a large amount of the nucleus pulposus material was found upon section of the spine (Fig. 28).

CASE 11. *Multiple Prolapses of the Nucleus Pulposus.* V. C., aged twenty-five years. She complained of pain in her dorsal and lumbar spine and of sleeplessness of four years' duration. She attributed her condition to a difficult labor four years before admission. A kyphos was present in the lower thoracic and lumbar region of the spine. Lateral x-rays showed the punched-out areas in the mid-dorsal and the lumbar spine which are characteristic of prolapses of the nuclei pulposi. She was relieved by a back brace.

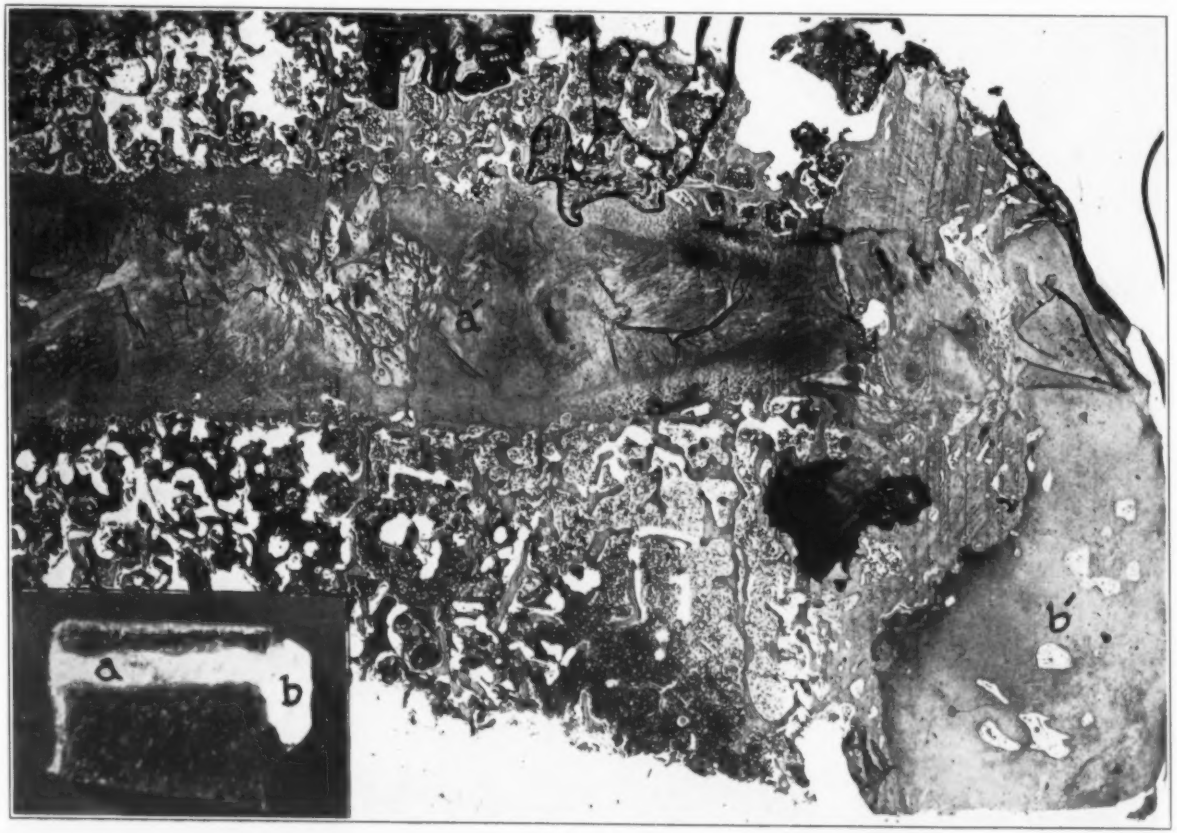

FIG. 29

FIG. 29

This specimen was obtained from the spine of a patient who died of generalized carcinomatosis. The finding in the spine was incidental and apparently had produced no clinical symptoms. In the gross specimen the nucleus pulposus has forced its way back through the annulus fibrosus, and into the spinal canal, elevating the periosteum and depressing the dura, forming a cartilage body (*b*), a part of which is illustrated in the photomicrograph (*b'*). The intervertebral disc (*a* and *a'*) is narrow and the cartilage plates show early degenerative changes characterized by fibrillation.

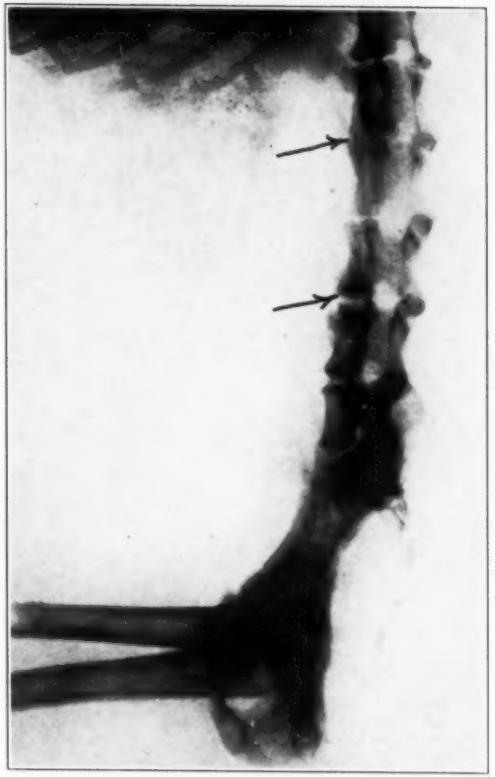

FIG. 30

Dog 815. Three months after operation. The loss of intervertebral space, sclerosis of adjacent portions of the vertebral bodies, and osteophyte formation are indicated by the arrows.

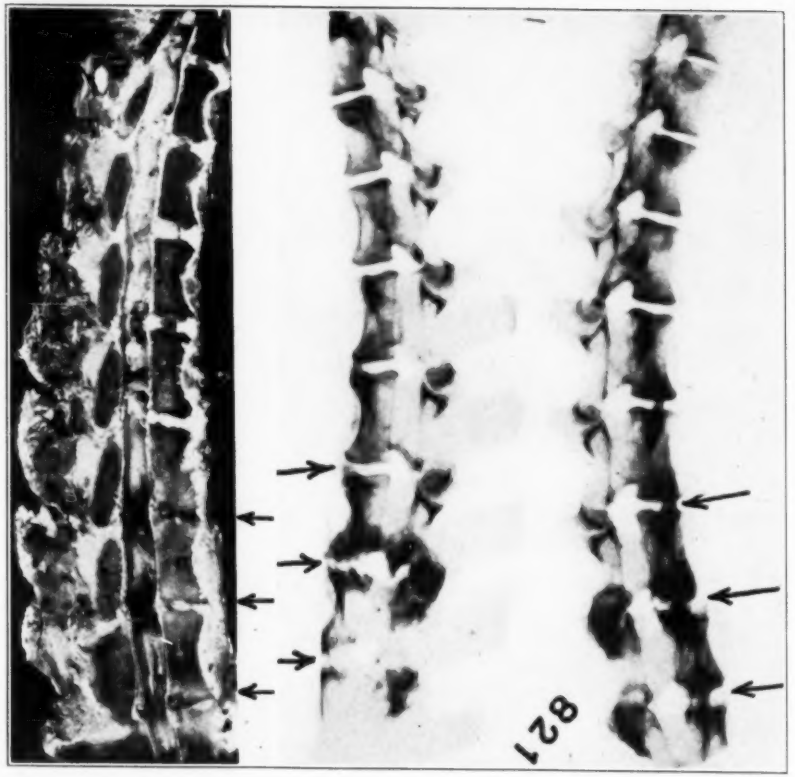

FIG. 31

Dog 821. Three months after operation. This spine, which has been sectioned longitudinally, demonstrates grossly and in the roentgenograms the sclerosis of vertebrae and osteophyte formation which followed removal of the nucleus pulposus material.

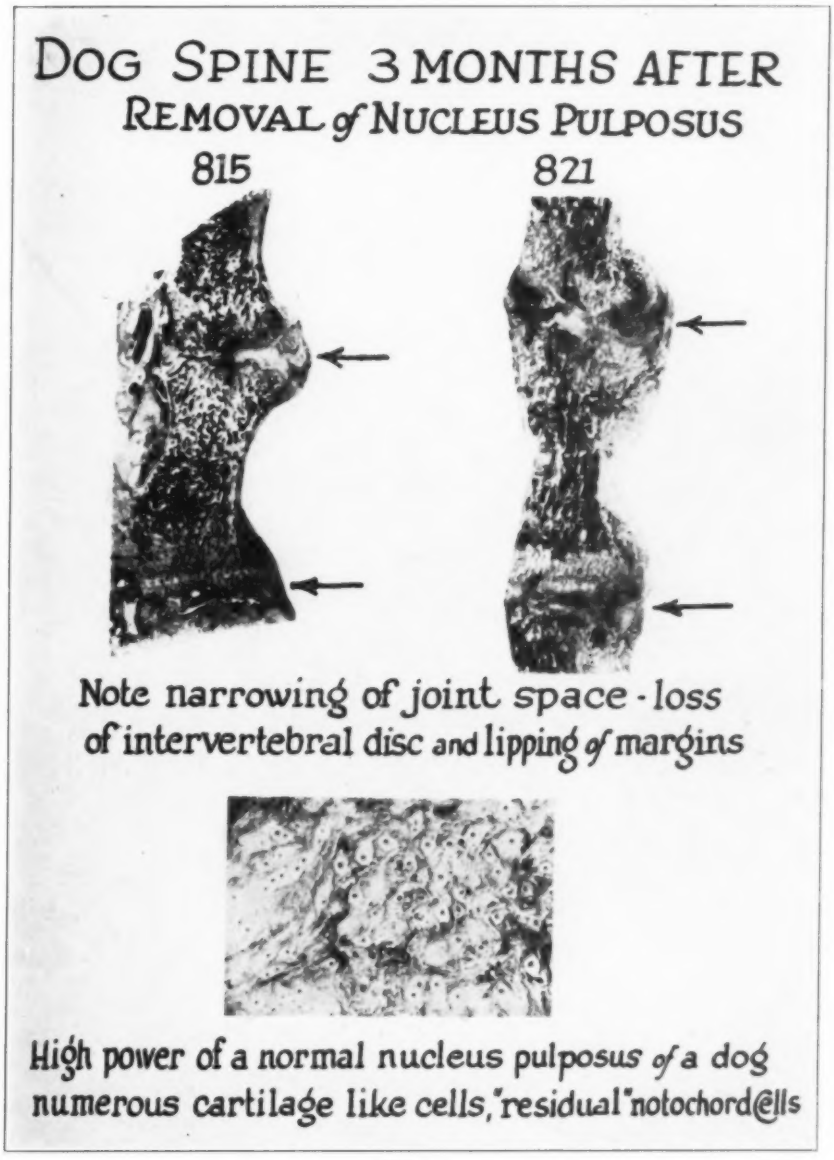
DOG SPINE 3 MONTHS AFTER
REMOVAL of NUCLEUS PULPOSUS
815
821
Note narrowing of joint space - loss
of intervertebral disc and lipping of margins
High power of a normal nucleus pulposus of a dog
numerous cartilage like cells, "residual" notochord cells

FIG. 32

Dogs 815 and 821. These reduced photomicrographs illustrate the similarity between the changes noted in these dog spines and those recognized clinically as osteoarthritis of the spine.

EXPERIMENTAL STUDIES OF THE NUCLEUS PULPOSUS

The first experimental studies of the nucleus pulposus were those of Ribbert[33] when, in 1895, he proved that the Virchow tumor known as ecchondrosis physalifora could be produced experimentally in the rabbit by puncturing the intervertebral ligament and permitting a portion of the

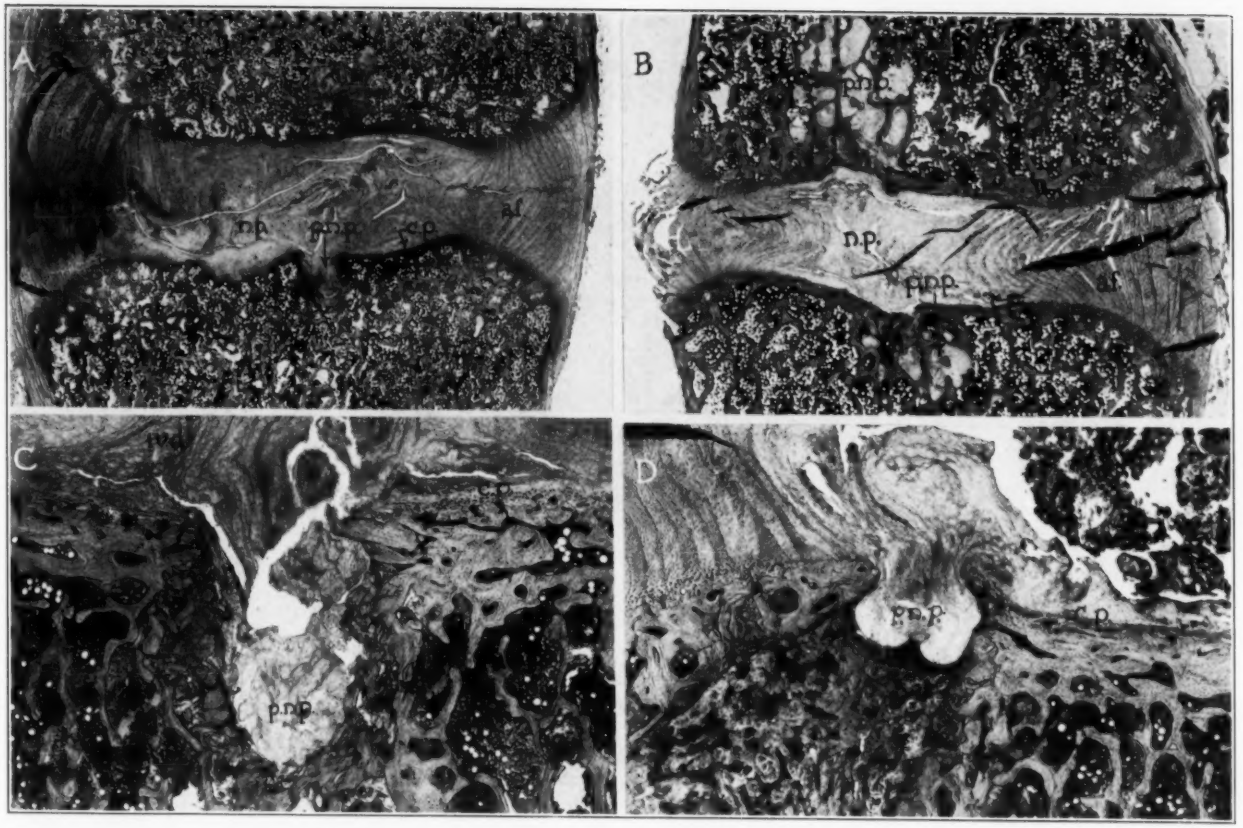

FIG. 33

FIG. 33

Photomicrographs of sections of spines of dogs in which the intervertebral disc was injured from two to five months before the animals were sacrificed. (One-half size.)

In *A* and *B* the anterior fibers (*a.f.*) of the annulus fibrosus were incised with a scalpel, permitting some of the nucleus pulposus (*n.p.*) material to escape. At the same time a curette was inserted and the cartilage plate (*c.p.*) was damaged, resulting in a small prolapse of the nucleus pulposus (*p.n.p.*), narrowing of the intervertebral discs, and sclerosis of the subchondral cortical bone.

In *C* a small drill was passed through the vertebral body, the cortical bone, and the cartilage plate of the inter-

FIG. 33 (*Continued*)

vertebral disc (*iv.d.*). Nucleus pulposus material has been extruded through the defect into the cancellous bone, forming a typical Schmorl cartilage nodule (*p.n.p.*). A similar prolapse is noted in *D* following fracture of the vertebral body with a heavy chisel, with a resultant break in the cartilage plate.

nucleus pulposus to escape. This nuclear material lying in the connective tissue and muscle near the ligament was found to grow for some time and to form a characteristic ecchondrosis physalifora, which he called a chordoma (Fig. 29).

Roux [34] has studied the effect of pressure on the intervertebral disc and the vertebrae themselves.

Püschel [15] estimated the water content of a series of normal and degenerated intervertebral discs in the various age-periods. Her results and our own have been described elsewhere in this paper.

In the hope that we might be able to reproduce experimentally some of the pathological conditions which clinically have been thought to be due to injuries or disease of the nucleus pulposus, we have undertaken a series of experiments. We chose as our subjects monkeys and adult dogs. The lumbar spine was exposed by intra-abdominal incisions and the dorsal spine by rib resection posteriorly and reflection of the parietal pleura from the sides of the vertebral bodies. The intervertebral discs were injured in various ways, and at several levels in the spine. A small drill was passed through the bodies of the vertebrae at an angle until the drill perforated the cartilage plate at the site of the nucleus pulposus. At another level a vertebral body was fractured by passing a wide chisel through it transversely and a third vertebra was fractured longitudinally so that the fissure extended to the cartilage plate. In a second series the annulus fibrosus was incised with a sharp scalpel. Upon withdrawing the scalpel a semi-fluid, gelatinous, slightly turbid material was immediately exuded in an amount of from five-tenths to one cubic centimeter, obviously under considerable pressure.

In our series of thirty-two dogs and two monkeys, only sixteen of the dogs survived the operation long enough to obtain results of value. In two dogs, in which the vertebral bodies were exposed by a paravertebral incision in the lumbar region and the intervertebral disc was opened with a small knife and the nuclear material was curetted out, there was a mild infection which persisted for from two to three weeks. In subsequent x-ray examinations (Fig. 30) the intervertebral discs were found to have completely disappeared and the adjacent bone surfaces became markedly sclerosed with spur formation and lipping of the anterior edges. These dogs developed a definite kyphosis (Fig. 31). They were sacrificed three months after operation and the spines were sectioned and studied microscopically. The discs at the site of injury had disappeared, the bone was dense, and there was marked hyperostosis and new bone formation very similar to that observed clinically in cases of marked osteo-arthritis of the spine (Fig. 32).

In the series of animals in which small drill holes were made through the cartilage plates, nuclear prolapses typical of the cartilage nodules described by Schmorl were found. All of these animals were sacrificed before sufficient time had elapsed to permit any marked bone sclerosis about the extruded nucleus pulposus material (Fig. 33).

Similar cartilage nodules were found extending into the cracks in the cartilage plates created by the chisel with which the vertebral bodies were fractured. In those vertebrae where the cartilage plate was not injured by the chisel, but where merely the bone was fractured, no prolapses were found.

In every instance where nucleus pulposus material had been permitted to escape, there was definite narrowing of the intervertebral disc and, when most of the nucleus was curetted out, the adjacent vertebrae showed early changes of typical hypertrophic or osteo-arthritis of the spine and fibrosis of the material remaining in the space previously occupied by the nucleus pulposus.

CONCLUSIONS

1. The assumption of von Luschka and of later embryologists that the intervertebral nucleus pulposus is a vestigial remnant of the notochord has been disproved. It is a highly specialized structure.

2. The nucleus pulposus is not formed from degeneration of the annulus fibrosus fibers as postulated by Virchow and Dursy.

3. This anatomical entity is formed by the proliferation and mucoid degeneration of the notochord cells, followed by a fibrocartilaginous invasion derived from the original mesenchymal intervertebral cells, which form a fibrocartilage envelope.

4. The cartilage plate and the epiphyseal ring are genetically one structure and are comparable to the epiphyses of the long bones.

5. The nuclei pulposi are essential for the normal physiological functions of the spine.

6. Loss of nucleus pulposus material as a result of trauma or disease is probably one of the frequent etiological factors associated with pain in the back and disability.

7. Clinical and experimental evidence has been presented to indicate that degenerative, hypertrophic arthritis of the spine may result from the loss of the intervertebral shock absorber and hydrodynamic ball bearing of the spine, the nucleus pulposus.

8. If the cartilage plate of the intervertebral disc of a dog is injured by a scalpel or drill, nuclear material prolapses into spongiosa and a cartilage nodule forms.

9. If the nuclear material is allowed to escape, the rest of the disc becomes thinned out and the margins of the adjacent vertebrae become sclerosed with subsequent marginal lipping.

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OSTEOGENESIS IMPERFECTA

With a Suggestion for Treatment *

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There is a condition of the bony skeleton in the human, which has been given various names, and which has been studied from the histopathological, pathological, biochemical, and clinical standpoints without disclosing any definite knowledge as to its etiology, and in which no apparently successful mode of therapy has been developed. We refer to the condition most commonly called osteogenesis imperfecta.

Hess has described two forms of the disease,—one, osteogenesis imperfecta congenita which occurs at or soon after birth; and the other, osteogenesis imperfecta tarda in which the symptoms appear in late infancy or early childhood. This latter is probably the osteopsathyrosis idiopathica which was described by Lobstein in 1834.

We wish to report the observations on two cases of this condition which were treated apparently successfully by the administration of thymus gland by mouth. This method of treatment was suggested to us by the work of Glässner and Hass in which, both in animal investigation and in clinical trial, they studied the effects of the administration of thymus on bone healing. The literature of this work can be divided into two groups: (1) the effect of thymus extirpation on the healing of fractures; (2) the influence of thymus injections or feedings on the healing of fractures. Experimental results would seem to indicate that thymus extirpation causes a smaller than normal amount of callus formation.

Using cats from the same litter, under ether anaesthesia, the left leg was fractured and in one-half of the animals the thymus was removed. One-half of the animals received no thymus, while the other half received daily injections (subcutaneously) of one cubic centimeter of thymus extract for fourteen days. Every eighth day x-ray films were taken and at the end of four weeks the animals were killed.

Results. The thymectomized animals showed less callus formation than the control animals, while the thymectomized cats who had received the thymus extract injections all showed a voluminous periosteal and medullary callus.

These experiments were repeated a number of times.

In the second series of experiments Glässner and Hass studied the effects of extracts of other endocrine glands on the healing of fractures. Using older cats of approximately the same weight they fractured the left leg and for twenty days thereafter gave daily injections of one cubic centimeter of different extracts, including egg albumin, testicular substance, and parathyroidin. The results of this work proved to their

* From the Department of Surgery, St. Mary's Hospital, Philadelphia.

satisfaction that, of all the extracts, the thymus exerted the best callus-stimulating effect. Next in line, although far behind, was parathyroid extract.

Following this work Glässner and Hass decided to try thymus extract in humans and they make the observation that man tolerates relatively large doses of thymus without harm. Two patients of the same age were selected upon whom they performed linear osteotomies for bow legs. One received thymus injections and the other was used as a control. A comparison of the films showed no difference between the two cases after four weeks, but three months later there was a marked change. The thymus-free patient had motion in the operative region and very little callus, while the patient who received the thymus-extract injections had completely consolidated periosteal and medullary callus.

CASE REPORTS

CASE 1.* D. McH., male, aged eight at the time of the first observation. This boy was seen at his home March 26, 1929, by the reporter, following a fall.

Physical examination revealed evidences of a fracture at the upper end of the right humerus and a fracture of the upper end of the right thigh. An x-ray taken immediately after his admission to St. Mary's Hospital disclosed a fracture of the surgical neck of the right humerus in good position and an intertrochanteric fracture of the right femur with slight decrease in the normal angle between the neck and the shaft. The fractured humerus was treated by rest and bandaging to the side. The fractured femur was fixed by a Whitman cast which was allowed to remain on for eight weeks. The boy returned to school the following September and sometime after that, a decided limp being noticed, he was questioned and complained of pain in the right ankle. X-rays at this time showed a fracture of both internal and external malleoli and a fracture across the lower end of the tibia with union in good position. In February 1930 he sustained a fracture of the middle of the shaft of the left femur for which he was treated at another hospital by a plaster case. After the removal of this case he returned to school and, on standing beside his desk, he placed his full weight on the left leg and turned his body and the femur gave way. Another x-ray taken at St. Mary's Hospital showed a fracture through the middle of the shaft of the left femur at the site of an old fracture; callus was small and not well calcified.

Suspecting the probability that this was a case of osteogenesis imperfecta tarda we further investigated his history with the following information: One of his clavicles was fractured at the age of five, followed by fractures of the other clavicle and of the left humerus following trivial falls; then followed fractures of the right humerus and right femur mentioned above and the fracture of the right ankle mentioned above, then the first fracture of the left femur and the recurrence. In one year, therefore, he fractured the right humerus, right femur, right tibia, and left femur, with recurrence of the latter fracture in about a year.

Aside from being a small boy who did not walk until eighteen or twenty months of age, and who did not talk until three years of age, his previous history was essentially negative. His father and mother, one brother, and five sisters are living and well and careful investigation failed to disclose any evidence of a susceptibility to fractures or blue sclerotics on either side as far back as can be determined.

Examination. The fractures mentioned above were found on physical examination and confirmed by x-ray. Except for a slight grade of anaemia, the red blood count being 3,930,000, all blood studies were within normal limits.

In July 1930, while wearing a brace on the left leg to prevent a tendency to turn in,

* Case 1 was presented before the Philadelphia Academy of Surgery in December 1931.

he fell and fractured the left tibia at the junction of the upper and middle thirds while the brace was on the leg. This fracture healed rapidly.

It was at this time that we reviewed the work of Glässner and Hass and placed this boy on thymus gland—two grains twice daily—and in the time that has elapsed since then no further fractures have occurred although this boy has led a normal active life, has been able to play ball, ride a bicycle, roller-skate, and has had numerous falls. Later on we suggested this treatment to Dr. A. Bruce Gill, who had seen this boy with us in consultation, and he very kindly gave us the report of Case 2.

Case 2. C. S., female. Admitted to the University Hospital January 31, 1930. Marked outward bowing of right femur and bowing of right humerus present.

Past Medical History. When nine months old she suffered a fracture of the right femur when turning in her crib. Was taken to the Jefferson Hospital where she remained eight months. Several months after her return home she had another fracture of the same bone and was taken to the Methodist Hospital where she remained nine months. At the end of another seven months she suffered a third fracture of the right femur. She spent nine months in the Children's Seashore Home at Atlantic City. All these fractures healed readily. Had had whooping-cough, chicken-pox, measles, and pneumonia.

Family History. Is the only child living. The first child was born deformed and lived but two months. Father and mother are living and well.

Operation. April 3, 1930. Manual osteoclasis of right femur to correct the deformity. Following the operation the fracture healed well and she was discharged from the hospital on June 19, 1930.

Readmitted to the University Hospital September 15, 1930, with a fracture of the lower third of the left tibia caused by a fall while walking.

On October 6, 1930, she had a fracture of the right tibia while lying in her crib, and on November 26, 1930, the right femur again was broken.

On November 30, 1930, she was put on thymus-gland medication, fifteen grains daily. No other fracture occurred until June 6, 1931, when there was a fracture of the upper third of the right tibia.

The administration of the thymus gland was continued until November. It was then stopped because her appetite seemed to be affected. Two months afterward she again had a fracture of the left femur (January 9, 1932).

During the period of administration of the thymus the child improved in general health. She lost her fear of being handled and began to walk. Her weight increased. X-ray examinations showed marked increase in density of the shafts of the long bones.

On her first admission to the hospital she had a hemoglobin of seventy-four per cent., and the blood count showed 3,500,000 red blood corpuscles and the white blood cells varied between 12,000 and 17,000. Blood calcium was ten and two-tenths milligrams per 100 cubic centimeters and blood phosphorus five milligrams. Her head was large and square. The anterior fontanelle was still open at five years of age. She was poorly developed and undernourished. The upper extremities were short and there was marked bowing of both humeri. She had a rachitic rosary. She had a slight exophthalmos and the sclerae were a bluish white. There were no neurological signs nor symptoms.

For a time she was treated with viosterol and calcium, but these were discontinued when the administration of thymus gland was begun.

Conclusions. Before thymus gland was given this patient was having a new fracture every few months. After this medication was begun, she did not have a fracture for seven months. The last fracture occurred seven months later and two months after the administration of thymus gland was discontinued.

CONCLUSIONS

Although the treatment suggested here may be empirical we believe that further trial should be given the administration of thymus gland in this condition because two definite patients have ceased having fractures

while thymus was being administered, and one of them at this writing has failed to have any fractures for approximately two years since the treatment was begun.

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CONGENITAL DISLOCATION OF THE HIP: THE TREATMENT AND RESULTS IN CASES UNSUITABLE FOR BLOODLESS OR OPEN REDUCTION

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The treatment of congenital dislocation of the hip in older children and in young adults has received considerable attention. This is also true of those early cases that show a shallow acetabulum and have more or less instability of the hip joint. Numerous operative procedures have been devised and subjected to clinical trial and investigation. We feel at this time that the shelf operation gives the best hope of providing a hip that is stable, painless, and functionally satisfactory. It is for this reason that we are reporting this series of cases.

During the past five years the shelf operation has been performed in twenty-three instances at the Children's Orthopaedic Hospital and in the private practice of Dr. C. F. Eikenbary, Dr. John F. LeCocq, and Dr. Edward LeCocq. Sixteen patients have been treated. The results have been, on the whole, very satisfactory. In the cases having a shallow acetabulum, with or without a partial luxation of the femoral head, the procedure has consisted of wedging the top of the acetabulum downward, then filling in and building a shelf above the head. In the frank dislocations, the method has been, in each instance, a turning down of a shelf from the side of the ilium over the head, the angle between the ilium and the shelf being filled in with bone chips taken from the iliac crest. In performing the operation the capsule is not entered, the shelf being formed entirely extracapsularly, just above the femoral head.

The results are here briefly summarized:

CASE 1. D. S. Age thirteen years. Bilateral dislocations.

July 2, 1928: Attempted reduction of right hip by open operation unsuccessful; so, at the same sitting, a shelf was formed.

September 10, 1928: Shelf operation, left.

April 17, 1929: Right hip practically ankylosed. Good shelf on left.

June 6, 1930: Subtrochanteric osteotomy of right femur, for correction of adduction and flexion deformity.

July 30, 1930: Little motion in right hip. Sixty degrees of motion on left side, good adduction, abduction, and rotation. Some limp on left side.

CASE 2. W. L. Age five. Right hip.

August 20, 1928: Manipulation and plaster. Successful reduction. Acetabulum very shallow.

January 4, 1932: Slight instability of hip because of shallow socket. Shelving done.

April 7, 1932: Good shelf. Hip stable. Practically no limp. Very good result. (See Figure 1.)

CASE 3. S. K. Age thirteen. Bilateral.

August 31, 1929: Shelf, right.

November 18, 1929: Shelf, left.

January 20, 1930: Plaster removed.

FIG. 1

Case 2. Before and after operation.

June 19, 1930: Hips stable.

September 29, 1930: Osteotomy of femur for correction of knock-knee deformity.

November 29, 1930: Good shelves and sockets. Walks well with only slight limp. Excellent result.

CASE 4. M. G. Age eleven. Left hip.

June 17, 1931: Shelf operation. Plaster for four months.

January 29, 1932: Walks with only a slight limp. Stable. Good range of motion. Excellent result.

(See Figure 2.)

CASE 5. Y. K. Age nine. Bilateral.

July 2, 1928: Open reduction, right.

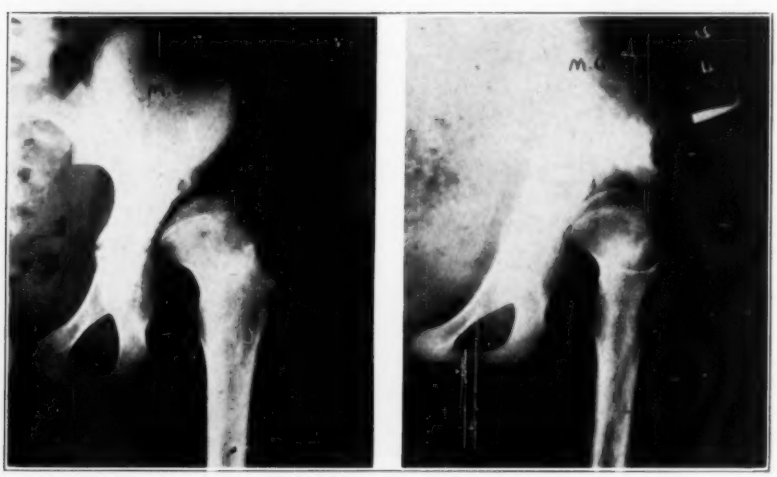

FIG. 2

Case 4. Before and after operation.

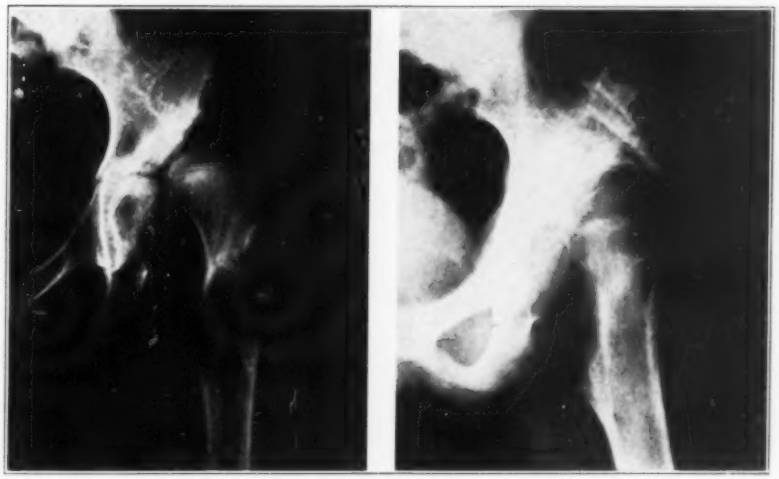

FIG. 3

Case 6. Before and after operation.

August 4, 1928: Reluxated. Reoperated, head reduced into acetabulum.
March 4, 1929: Shelf operation, left hip. Right hip very stiff. Manipulated.
November 25, 1929: Arthroplasty, right.
June 18, 1931: Right hip ankylosed. Left hip stable; has good motion. Walks fairly well.

CASE 6. D. M. Age ten. Left.
May 11, 1931: Shelf operation.
March 18, 1932: Walks without a limp, and without fatigue. Excellent result. (See Figure 3.)

CASE 7. E. B. Age three. Bilateral.
June 11, 1930: Manipulation.
November 12, 1930: Right hip in place. Left dislocated.

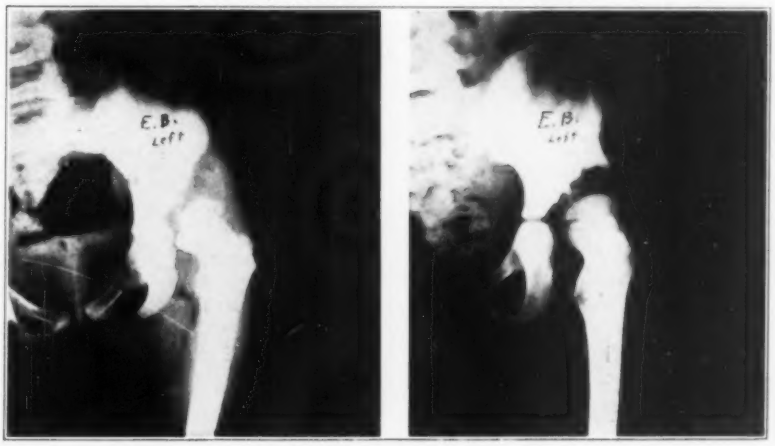

FIG. 4

Case 7. Before and after operation.

FIG. 5-A

Case 10. Before operation.

FIG. 5-B

Case 10. After operation.

April 24, 1928: Shelf operation, left.
May 18, 1928: Shelf, right.
February 12, 1929: Walking well.
May 18, 1931: Walks very well, with a slight waddle. Does not tire and has no pain. Excellent result.
(See Figures 5-A and 5-B.)

CASE 11. L. E. Age six. Right.
July 8, 1931: Shallow acetabulum. Hip unstable. Shelf operation performed.
September 1, 1931: Good shelf. Normal motion. Excellent result.

CASE 12. G. B. Age twenty years. Bilateral.
January 9, 1932: Shelf operation, left.
November 17, 1930: Shelf operation, left.
January 21, 1931: Excellent position and shelf present. Some instability of right hip.
March 22, 1931: Shelf, right.
June 24, 1931: Good function in both hips. Excellent result.
(See Figure 4.)

CASE 8. L. M. Age seven. Right.
September 1, 1928: Open reduction. Shallow acetabulum.
December 27, 1928: Plaster removed. Hip reluxated.
February 25, 1929: Shelf operation.
October 3, 1929: Fair motion. Hip stable. One inch of shortening.
August 20, 1931: Walks very well. Motion limited. Fair result.

CASE 9. Z. W. Age thirteen. Bilateral.
April 15, 1929: Shelf, right.
May 6, 1929: Shelf, left.
October 20, 1929: Walking without support.
November 5, 1930: Walks remarkably well. Most excellent result.

CASE 10. R. Y. Age nineteen. Bilateral.

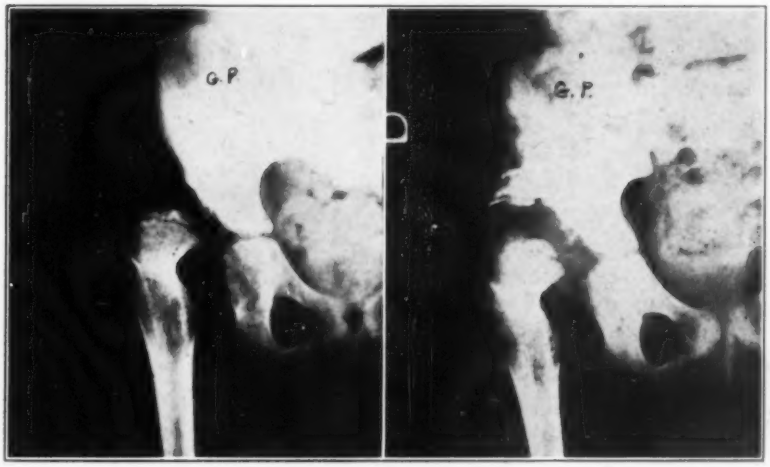

FIG. 6

Case 13. Before and after operation.

March 10, 1932: X-ray shows good shelf. Walking with aid of crutches and complains of no pain. Will obtain good result.

CASE 13. G. P. Age nine. Right.
January 25, 1932: Shelf operation.
March 25, 1932: Excellent shelf present.
April 14, 1932: Walks with very little limp. No pain. Very good result.
(See Figure 6.)

CASE 14. V. T. Age four. Bilateral. Shallow sockets present on both sides.
October 28, 1929: Open reduction, right.
January 27, 1930: Open reduction, left.
March 20, 1930: X-ray shows that both hips have redislocated.
August 17, 1931: Shelf, right.
September 14, 1931: Shelf, left.
November 28, 1931: Good shelves present. Walking.
January 12, 1932: Walking very well. Shelves holding satisfactorily.
Following this the patient developed Pott's disease and she is now recumbent on a Bradford frame.

CASE 15. R. S. Age five. Right.
August 15, 1930: Shelf operation.
December 19, 1930: Good shelf. Still has limp.
February 12, 1932: Good stability and motion. One-half inch of shortening. Walks with a slight limp. No pain.

CASE 16. P. G. Age three. Right.
January 23, 1932: Very shallow acetabulum present.
January 25, 1932: Shelf operation.
April 16, 1932: Plaster removed. X-ray shows excellent shelf. Good mobility, no shortening.
May 14, 1932: Normal range of motion. Slight limp still present. Will probably obtain a perfectly normal hip.

CONCLUSIONS

The shelf operation has been performed in twenty-three instances, for the relief of symptoms due to old, unreduced congenital dislocations of the hip, and for the purpose of providing stability in those hips having shallow sockets, with or without a partial dislocation of the femoral head.

Favorable results have been obtained in nineteen of the operations. Stability has been secured, the limp has been lessened or corrected, and pain has been relieved.

Two of the cases gave only fair results, a marked degree of shortening being present.

Two of the operations resulted in ankylosis of the affected hips. It is to be noted that in each of these cases the shelf operation had been preceded by an attempted open reduction.

We feel that in the older cases, where open reduction is not likely to be successful, the shelf operation is preferable to open operation and reduction. The latter procedure often results in ankylosis of the affected hip, whereas the shelf operation, in nearly every instance, gives a freely movable hip which is painless and has good function.

RADIAL EXOSTOSIS COMPLICATING ANTERIOR DISLOCATION OF THE ELBOW

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Anterior dislocation of the elbow is an extremely uncommon condition. In 1922 Cohn [1] collected twenty-two cases from the literature and added one of his own. In seven of Cohn's cases the forward dislocation was associated with a fracture of the olecranon or coronoid process. In 1923 Tees [2] collected twenty-eight cases of which eight were accompanied by fracture of the olecranon. Last year Simon [3] collected thirty-one cases of anterior dislocation of both bones of the forearm and added one of his own. In the case of anterior dislocation of the elbow reported by Tees and McKim [4] the humerus had herniated through the lower end of the triceps.

In posterior dislocations of the elbow Cotton [5] points out that the stripped-up periosteum "is the source of the massive formation of new bone behind and to the outer side of the joint, regularly found at operation on old luxations". This complication is particularly evident in anterior dislocations. In the words of Cohn [1], "In all cases which have been verified by operation or autopsy there has been an extensive laceration of the ligaments about the joint and a stripping-up of the muscles in the immediate vicinity from the respective bones".

The stripping-up of the attachment of the brachialis anticus from the lower end of the humerus, with the resulting hemorrhage and possibly with the displacement of osteogenetic cells, predisposes toward ossification in this region (See Blencke [6]). Osteomata of the brachialis anticus following posterior dislocation have been reported by Costantini [7]; and, following a dislocation of the elbow of undetermined variety, by Lucchese [8]. In their textbook Baetjer and Waters [11] show a reduced dislocation of the elbow, followed by a "deposition of bone in the torn ligaments, producing ankylosis".

It would seem that the conditions for the formation of an ossification complicating dislocations of the elbow would be more favorable in the anterior variety of dislocation than in the posterior, because of the stripping-up of the brachialis anticus. In the following case the osteoma or exostosis involved the brachialis anticus, but seemed to originate from the head of the radius. It followed a severe compound anterior dislocation of the elbow, accompanied by fracture of the ulna. The details of the treatment of the fracture of the ulna have previously been reported as part of a paper on the operative treatment of fractures. In brief:

The patient, W. K., aged thirty-four, sustained a compound anterior dislocation of the left elbow, accompanied by a fracture of the ulna with loss of substance, on July 3,

FIG. 1

Exostosis of the head of the radius following anterior dislocation of the elbow with severe compound fracture of the ulna.

FIG. 2

Exostosis shown in Fig. 1, but with the arm flexed, showing the exostosis apparently impinging upon the humerus.

1931. The split shaft of the ulna was approximated by a Parham band and the olecranon process was wired to the shaft of the ulna across the gap occasioned by the loss of bone substance. The extensive wound was treated by the Carrel-Dakin method and eventually healed. The wires and band were removed.

Nine months after the injury, x-ray examination (Fig. 1) showed a curved exostosis originating from the head of the radius. This bony protuberance completely eliminated supination and pronation and, moreover, as is evident from the x-rays, seemed to explain the limitation of flexion. The arm could be flexed to no less than a right angle, in which position the distal end of the exostosis seemed to impinge upon the humerus (Fig. 2).

On March 10, 1932, a longitudinal cubital incision was made under ethylene anaesthesia. A bloodless field was secured by the use of a tourniquet. Using the biceps tendon as a guide, the head of the radius was located. The exostosis was carefully dissected free and removed. The head of the radius was then removed by means of a Gigli saw. Supination and pronation of the forearm now became possible, but flexion was unimproved. A separate mesial incision was then made and part of the coronoid process of the ulna was chiseled off. Flexion was still obstructed and it was thought to be due to the unusual conformation of the joint or to shortening of the triceps.

On April 30, 1932, seven weeks after the operation, seventy-five per cent. of supination and pronation was present, but flexion was still limited to about ninety degrees (Figs. 3 and 4). The patient is undergoing active physiotherapy and it is expected that considerable further improvement will occur. The patient has found the arm much more useful since the ankylosis preventing supination and pronation has been removed.

SUMMARY

1. Anterior dislocation of the elbow is rare and may be accompanied by fracture of the ulna.

FIG. 3

Appearance of the elbow shown in Figs. 1 and 2 after excision of the head of the radius.

FIG. 4

Lateral view of elbow shown in Fig. 3, showing excision of the head of the radius and removal of a part of the coronoid process of the ulna.

2. Anterior or posterior ossification in the soft parts may be a complication of anterior or posterior dislocation of the elbow.

3. Such ossification may cause serious interference with supination and pronation or with flexion of the elbow, and often should be removed surgically.

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TENDINITIS OSSIFICANS TRAUMATICA

BY HERBERT L. BRUMBAUGH, M.D., CINCINNATI, OHIO

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The metaplasia of tissues has always held considerable interest. The production of bone at anatomical positions not usually found to be bony has always aroused more than a transient interest. The "bony shoulders" of the German soldiers and the "bony thighs" of certain horsemen have been the subject of a great amount of comment both in professional and lay literature.

The condition of tendinitis ossificans closely resembles myositis ossificans. It has been described as a very rare condition usually traumatic in origin [1]. The diagnosis has usually been made by roentgen examination; often, however, by operation. Two methods for the production of this condition have been advanced,—first, displacement of fragments of periosteum into a soil fertile for osteogenesis; second, an actual metaplasia of tendon fibers into cancellous bone [2]. Both of these would undoubtedly require trauma. The histological studies of Weidenreich [3] tend to show that "the osteoblasts are the usual fibrous cells without any specific endowment. They may be developed in every connective tissue under certain conditions, among which the increased afflux of lime salts seems to be of the greatest importance." Leriche's theory of ossification [3] requires two conditions,—first, an embryonic tissue formation; second, an afflux of lime salts. Trauma, causing minute hemorrhages, can easily give rise to granulation tissue, which in reality is a form of embryonic tissue. It is hard to show in many cases how trauma would cause the second condition to be fulfilled. Bone atrophy which would result in an afflux of lime salts to the traumatized tissue can rarely be demonstrated by the roentgen film.

The mesodermal origin of both bone and tendon has been established. The thesis has been advanced that bone will undergo the same changes as soft tissue which has a common origin, modified by the mechanical stresses and static alignments under which it is found. The reverse might be proposed,—namely, that soft tissue can undergo the same changes as bone under similar conditions.

Esau [4] reported a case which developed acutely on an apparently infectious basis and required surgical treatment. In 1851, an autopsy report in The Transactions of the Pathological Society of London [5] gave an instance of ossification in the psoas, iliacus, semimembranosus, and semitendinosus tendons in a man of seventy, who had been bedridden with chronic arthritis for twelve years. The German writers have reported a number of cases, pointing out the periosteal origin as the more likely

* Service of Dr. Albert H. Freiberg.

FIG. 1

Roentgenogram of knee before operation, showing complete ossification of the patellar tendon.

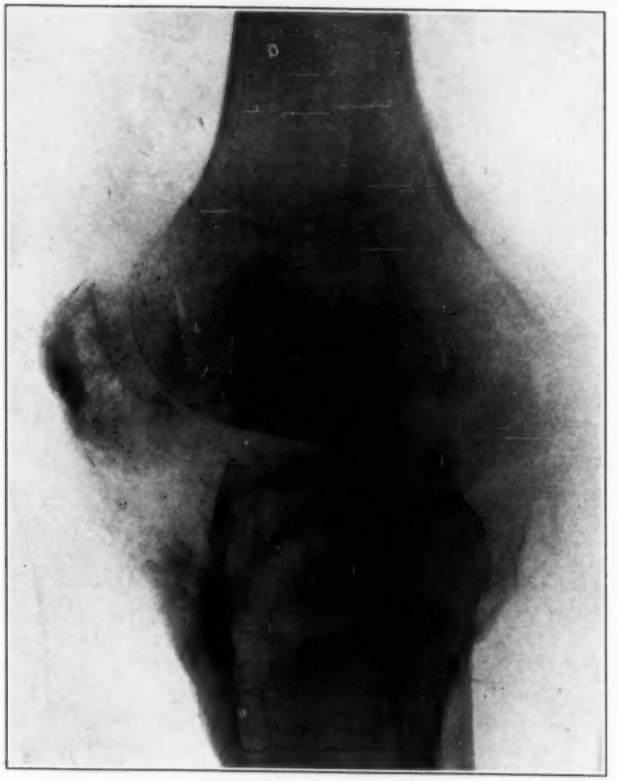

FIG. 2

Roentgenogram of knee after operation. The bony mass has been removed. Braided silk sutures were used to replace and restore the tendon.

explanation. Nearly all had a history of trauma. Seven cases have been reported showing ossification of the tendo achillis. Those reported by Horing [6], [7] and Densow [8] were undoubtedly traumatic in origin. Koehnlein [9] reported one case resulting from osteomyelitis of the calcaneum. Cases reported by Steiger [10], Jacobsthal, and Meyers could not be definitely attributed to trauma. An equal number have been reported involving the ligaments of the knee. Haglund [13], Sonntag (2 cases), Beaher, and Koehnlein (3 cases) reported cases involving these structures, all of which apparently had their origin in trauma. It is interesting that in the case reported by Beaher, the patient was a professional dancer. Frangenheim [11], Oliver [12], Koehnlein, and Fiedler reported cases of traumatic ossification in tendons of the elbow. Von Seemen and Koehnlein reported like cases but did not associate trauma with the etiology. The triceps tendon was usually involved. In only two of the reported cases was fracture noted as the result of the original injury.

CASE REPORT

H. D., aged thirty-two, male, colored. Porter by occupation, but frequently engaged in both amateur and professional tap-dancing exhibitions. Entirely well before the onset of his present illness. Admitted because of pain and limitation of motion in the right knee. Trauma had been sustained eight months previously by a fall on this knee. This was followed by intermittent dull, aching pain for four months which then became constant and moderately severe for the four months preceding his admission. This pain had been increased by weight-bearing and relieved temporarily by rest and heat. The past history revealed an infection of both gonorrhoea and syphilis. There had been no treatment for the latter.

The right knee presented the only interesting physical signs. They were: swelling anteriorly over the lower half of the patella, visible and measurable atrophy of the thigh and calf muscles, tenderness over the lower patella and patellar tendon, periarticular thickening of soft tissues, slight increase in local heat, definite spasm of the hamstring muscles, flexion to 150 degrees with full extension.

Roentgen examination showed a bony mass between the lower pole of the patella and the tibial tubercle, occupying the position of the patellar tendon. The Kahn reaction was strongly positive. The urine and blood examinations were insignificant.

At operation, a bony mass, replacing the patellar tendon with only a small membranous portion of the tendon remaining anteriorly, was found. The bony mass was completely excised. This procedure caused a rent in the remaining portion of the tendon approximately one and a half centimeters long. Braided silk sutures were woven back and forth in an attempt to restore the continuity and to strengthen the part remaining. The wound was closed without drainage. The extremity was immobilized in a long leg plaster cast with the knee in full extension. On histological examination this mass was found to be normal cancellous bone. The convalescence was com-

FIG. 3

Gross appearance of bony mass removed at operation.

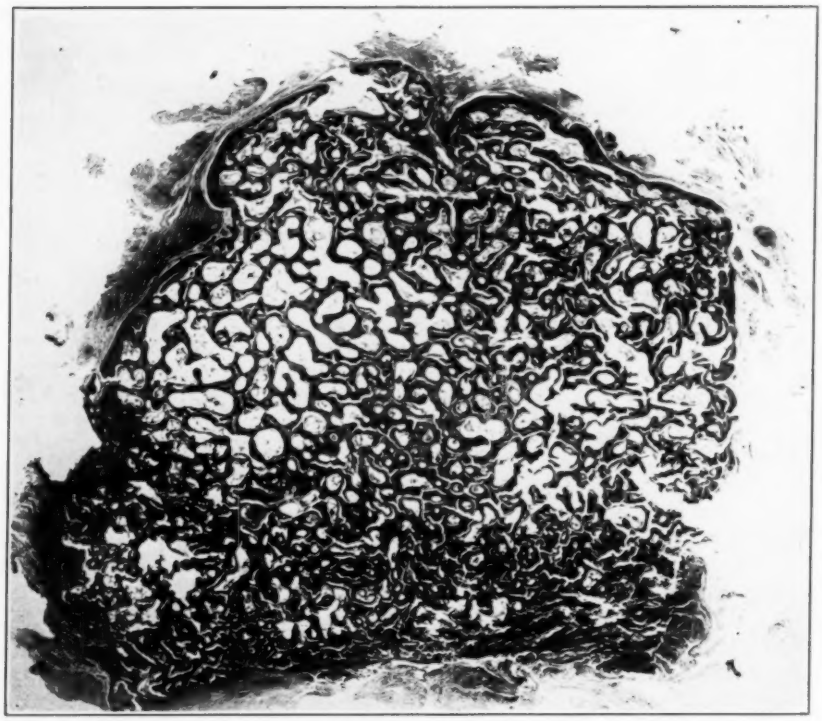

FIG. 4

Photomicrograph (low power) shows tissue removed to be normal cancellous bone.

plicated by a phlebitis which was easily controlled. The cast was not removed for six weeks.

Following the removal of the cast, physiotherapy, consisting of baking, massage, and stimulation with galvanic current, was instituted. After a few days active motion was encouraged. In approximately two weeks, the patient was actively flexing his knee again to 150 degrees and bearing weight without pain. He was discharged to the out-patient dispensary for further physiotherapy as the range of motion was rapidly increasing. After several visits he did not return for treatment. He reappeared after two months, having had no treatment, at which time examination showed motion to have increased satisfactorily. He was flexing his knee to 100 degrees with full extension. He was well pleased with the result.

FIG. 5

A. Anterior view. *B*. Lateral view. Photograph of the knee shows a slight flexion deformity and slight quadriceps atrophy, otherwise the gross appearance of the knee before operation showed nothing remarkable.

CONCLUSIONS

1. A case of tendinitis ossificans traumatica is reported. We believe that it was definitely due

to a proliferation of the periosteum resulting from trauma. This is a rare condition; only eight cases of similar nature have been reported. So far as we are able to learn the patellar tendon has not been the site of such a process in any of the reported cases.

2. Two cases of a rarer type, apparently due to an actual metamorphosis, have been reported.

3. In the proliferative type, surgical treatment to remove the mass, replace a functional mechanism, and prevent further proliferation is necessary. In the type due to a metamorphosis of tissue, simple excision only is indicated.

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FRACTURE OF THE ZYGOMA

BY OTHO C. HUDSON, M.D., HEMPSTEAD, LONG ISLAND, N. Y.

Fractures of the zygoma are usually associated with fractures of the malar bone. This fracture is given little space in the standard textbooks, and isolated cases have been reported from time to time.

Formerly the fractures of the zygomaticomalar arch were rare. However, with the advent of the automobile and airplane accidents its prevalence is increasing. The fracture is produced by a direct blow or fall on the zygomaticomalar arch. The injury occurs more frequently in the male.

The literature was reviewed and summarized by Roberts in 1928. Since that time few cases have been reported.

The treatment as a rule has been directed toward the malar bone which is depressed and associated with the fracture of the zygoma. Depressed malar fractures may be elevated as advocated by Roberts by a stab wound over the bone and elevation after fastening a special corkscrew-like instrument in the bone. Stacy advises a skin incision below the external canthus and then elevation with a periosteal elevator beneath the

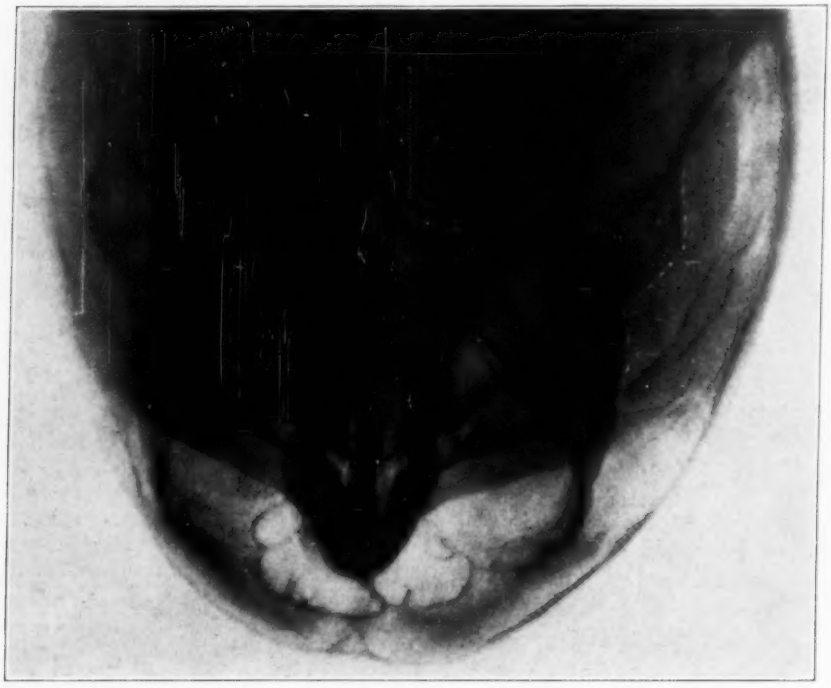

FIG. 1

X-ray showing depression of zygomaticomalar arch before operation (outlined).

malar bone. Wielage makes an incision in the mucous membrane within the mouth and elevates the bone with an elevator passed upward beneath the cheek. Opening the antrum from within the mouth and then elevating the depressed bone is used, but this method is more prone to infection.

The classical reduction of a fracture of the zygoma, as stated by Matas, is still useful. A long, full-curved Hagedorn needle threaded with silk as a carrier is made to penetrate the skin about one inch above the mid-point of the displaced fragment. The needle is carried well into the temporal fossa under the bone and then elevated so that the point of the needle emerges about one-half inch below the lower border of the broken bone. As the needle is pulled out, a strong silver wire is attached to the silk carrier and dragged through the track of the needle. The ends of the wire are twisted to form a loop upon which traction can be made upward until reduction is secured.

Fractures of the zygoma have also been reduced by open operation with incisions above or below the arch and elevation with an elevator.

Ivy and Curtis report a case where malunion of the zygomatic arch resulted in fixation of the lower jaw, due to callous and fibrous adhesions

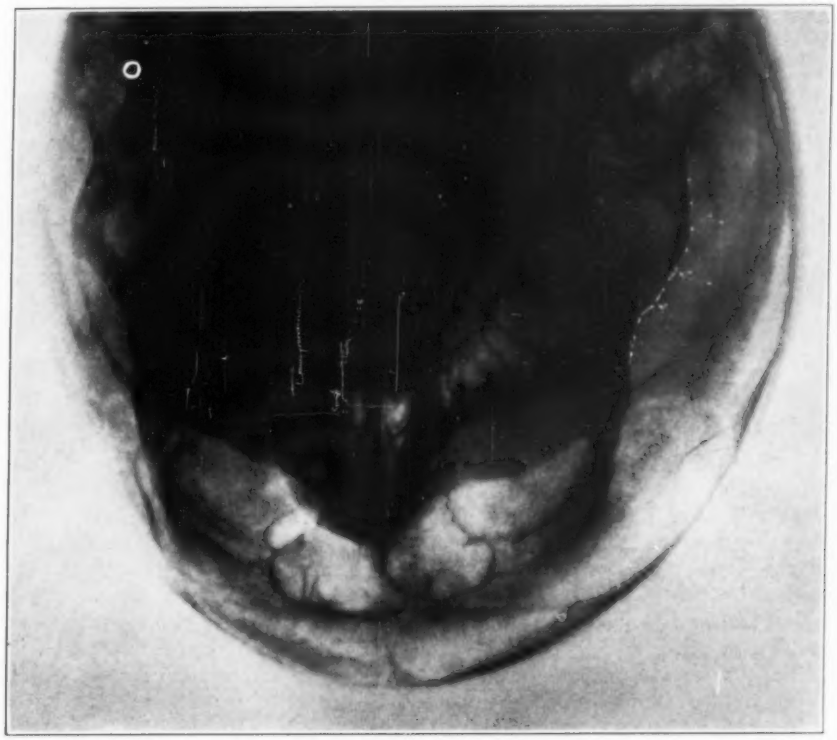

FIG. 2

X-ray showing elevation of depression of zygomaticomalar arch (outlined).

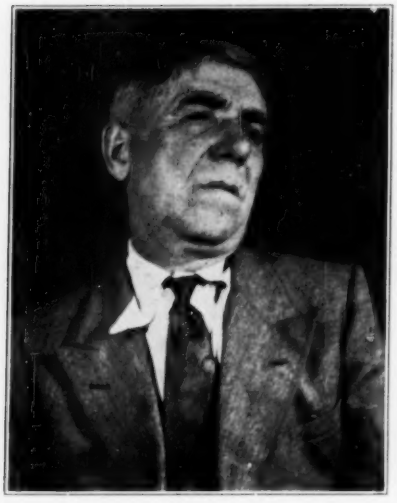

FIG. 3

FIG. 4

Showing the depression and maximum amount which mouth could be opened previous to operation.

connecting the depressed zygomatic fragments with the coronoid process of the mandible.

Fracture of the coronoid process of the mandible can occur with these fractures.

The symptoms are pain in the region of the fracture, pain on movements of the jaw, difficulty of moving the jaw due to associated injury of the masseter muscle, depression of the face in front of the ear, crepitus, swelling of the face, and tenderness at the site of the fracture.

The diagnosis is made by examination and special x-rays to show the zygomaticomalar arch. Treatment should be instituted early, for union is rapid and may be clinically solid in ten to fourteen days.

We are reporting an isolated case of fracture of the zygomatic arch seen seven days after the accident. In this case union of the fragments was beginning and the jaw was fixed due to a mechanical bone block formed by the depressed fragments, so that the patient could not open his mouth.

The case report of G. U., aged forty-eight years, white, Polish.

This patient had been in perfectly good health all his life until January 19, 1932, when the wagon which he was driving was struck by a taxi, throwing him to the street. He landed on the right side of his face. He had immediate pain and disability in the face and could not open his mouth. He was unable to sleep on that side of his face or to touch the site of injury and had extreme pain on any attempt at chewing. When first seen he was living on a liquid diet. His chief complaint when seen on January 26, one week following the accident, was inability to open his mouth. Patient complained of some pain over the right temporomandibular joint.

An examination revealed a patient who was an elderly male adult in good general condition. His teeth were in fair condition. He was able to open his mouth for about one-fourth inch, but on doing this had pain in the right side of his face. There was swell-

FIG. 5

FIG. 6

Showing the end result with slight thickening at area of operation.

ing of the entire right side of the face and a considerable depression about midway between the ear and eye on the right. This depression was found to be along the zygoma. There was no depression of the malar bone in the region of the eye. Crepitus was not present over the depression. There was infiltration of all the muscles on the right side of the face. The left temporomandibular joint was not tender. Motion of the lower jaw was possible only for separation of the teeth for one-fourth of an inch.

An x-ray showed a comminuted fracture of the right zygomatic arch with marked depression of the fragments. X-rays of the right temporomandibular joint did not reveal any bony pathology.

The operation was done under two per cent. novocain infiltration of the skin and deeper structures. An incision about one inch long was made along the lower border of the zygoma. Branches of the facial nerve were isolated and retracted. The masseter muscle was split in line with its fibers. At open inspection it was found that the patient could not open his mouth because of a mechanical block made of the bony fragments lying immediately anterior and posterior to the coronoid process of the mandible. With an aneurysm needle the anterior fragments were elevated. Immediately afterward the patient could open his mouth about three-fourths of an inch. The posterior fragments were then elevated. Plain catgut was used to suture up the subcutaneous layer and dermal for the skin.

After the operation the patient had considerable swelling of the face and complained of numbness and tingling along the inferior maxilla. No sensory changes were noted however. The sutures were removed on the fourth day. At that time the patient was able to open his mouth so that his teeth were separated about one inch. Ten days after operation the patient said he felt normal and was able to chew and could open his mouth normally. If his mouth were kept open for a long period of time, however, pain was felt. The patient's face appeared normal except for a slight prominence in the middle of the zygoma due to overelevation of the middle fragment.

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MASSETER PARALYSIS IN ANTERIOR POLIOMYELITIS

TREATED BY A SPECIALLY CONSTRUCTED HELMET

CASE REPORT

BY MAURICE H. HERZMARK, M.D., NEW YORK, N. Y.

This case is being reported because of the unusual type of paralysis, and the unique method in which it was treated. In a series of thirty-six cases of recent anterior poliomyelitis, studied on the Service of Dr. Kleinberg, at the Hospital for Joint Diseases, New York, one case of bilateral paralysis of the masseter muscles was observed.

This case was seen in a child four years of age. The acute symptoms of the illness occurred in August, 1931, and paralysis set in shortly after the onset of the illness. While under observation at the Willard Parker Hospital, it was noted that the child had difficulty in swallowing, and there was paralysis of both lower extremities and the right upper extremity. On expiration of the quarantine period, the patient was transferred to the Hospital for Joint Diseases where he came under our observation.

Twenty days after the onset of the acute illness, on admission to the Hospital for Joint Diseases, the examination showed: a child in poor general condition, undernourished and underdeveloped; speech very much disturbed and almost incoherent; the muscles of the face very weak, especially the left facial. The mouth hung open and the ability to close it was lost except by approximating the lips without moving the lower jaw. The right sternomastoid muscle was paralyzed. When the jaws were closed passively the child was able to open them, but he could not close them even when the head was in the recumbent position. The right upper extremity, the abdominal muscles, and the muscles of the back were also paralyzed. Both lower extremities showed evidence of paralysis and weakness of many muscles.

FIG. 1

Front view of the plaster-of-Paris helmet and chin piece, showing the mouth held closed by means of elastic bands attached to hooks. Note the normal appearance of the lips.

FIG. 2

A side view, showing the hinge and the elastic band which holds the jaw closed.

FIG. 3

The mouth is open because of paralysis of the masseter muscles. The patient is unable to approximate the upper and lower teeth.

FIG. 4

The lips are approximated, but the jaw is in the same position as that shown in Fig. 3.

The problem of immobilization of the extremities, in order to prevent deformity, was quite simple; and, in accordance with the routine followed out in all recent anterior poliomyelitis cases, a plaster-of-Paris double hip spica and right shoulder spica were applied, holding the extremities in a neutral attitude. The problem of supporting the lower jaw, to prevent relaxation of the masseter muscles, presented some difficulty. Support of the jaw with bandages was unavailing, because they could not be held in place very satisfactorily. So a special plaster-of-Paris helmet was constructed, molding the plaster about the chin held firmly against the maxilla. This was then trimmed and hinged at the temporomandibular joint, and, by means of elastic bands, the chin piece was made to keep the jaws closed. This helmet functioned very satisfactorily, and the child was able to open his mouth against the slight resistance of the elastic bands, and to chew soft foods. The helmet was kept in place constantly, except when it was necessary to remove it for hygienic purposes. After two weeks, it was observed that on removal of the helmet, there was a slight return of power in the masseter muscles, so that the child could approximate his jaws. At the expiration of six weeks, the plaster-of-Paris spicas were removed, and the helmet was no longer needed.

An examination of this patient made five months after the onset of the paralysis showed complete recovery of the muscles controlling the face and jaws. There was also almost complete recovery of the other paralyzed muscles.

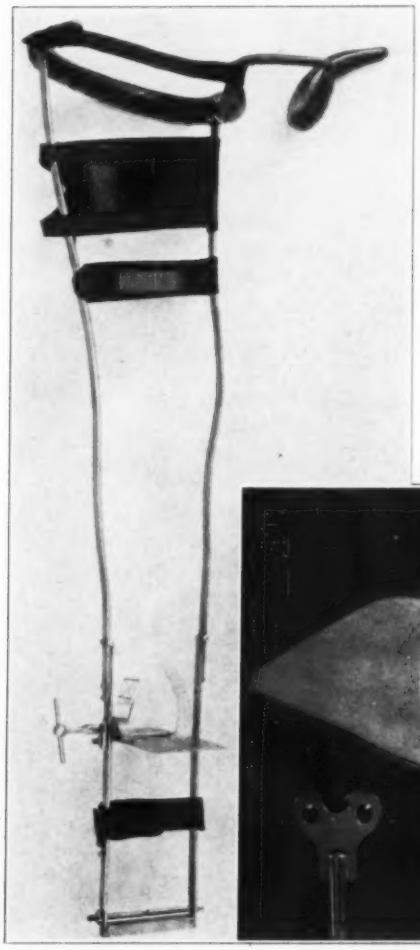
CONCLUSION

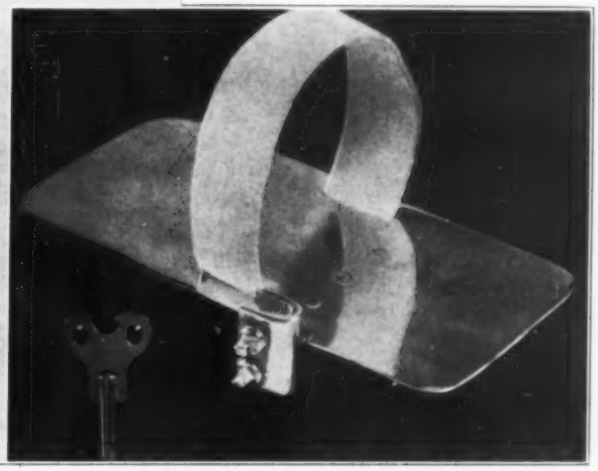
A case of bilateral paralysis of the masseter muscles, following anterior poliomyelitis, is reported to illustrate the support of these muscles by means of a specially constructed helmet made of plaster-of-Paris. This helmet may immobilize and support the lower jaw, without interfering with food intake. The quick return of power under this treatment is indicative of its value in alleviating so distressing a condition.

A FOOT PLATE FOR LEG SPLINT

BY THOMAS F. WHEELDON, A.M., M.D., F.A.C.S., RICHMOND, VIRGINIA

We have for a good many years used a great many Bradford abduction splints. The only objection which we have had to these splints has been the fact that it has been difficult to keep the foot at a right angle while supplying proper traction. After some consideration, the foot plate below illustrated was designed. A description of the plate further than the illustrations is unnecessary, except to state that it is made from rustless steel. It has the advantage of being easily moved up and down the splint, is interchangeable from right to left, is tightened on the splint with the same key which tightens the traction band of the splint, and allows support for the forefoot while still providing proper traction. The foot is comfortably held in place by a webbing band as illustrated. The plate can be used either in recumbency or after the patient has become ambulatory. The illustration shows the plate at a rather high level. This was done in order that its high range of position could be seen. The plate has now been in use for several years by us and we find it very practical and indispensable.





A NEW COMBINED SKIN ISOLATION CLIP AND RETRACTOR

BY G. KENNETH COONSE, M.D., COLUMBIA, MISSOURI

From the Department of Orthopaedic Surgery, University of Missouri

A satisfactory combined skin clip and retractor has been developed for operations on the femur and has proven extremely useful in other straight incisions of the extremities, back, abdomen, etc. For example, it can be used to excellent advantage in spinal fusion work. These clips are relatively inexpensive and have removable teeth (See illustration). It is possible to apply them quickly and easily by means of special clip "holders". After applying the clips in the usual way throughout the length of the incision, a long, flat piece of metal is slipped through the mid portion of the clips. The metal bar is somewhat smaller than the space within the clip, thus allowing a certain amount of motion upward and downward of the individual units. This is often of benefit when traction on a particular portion of the wound is required. Small metal balls are

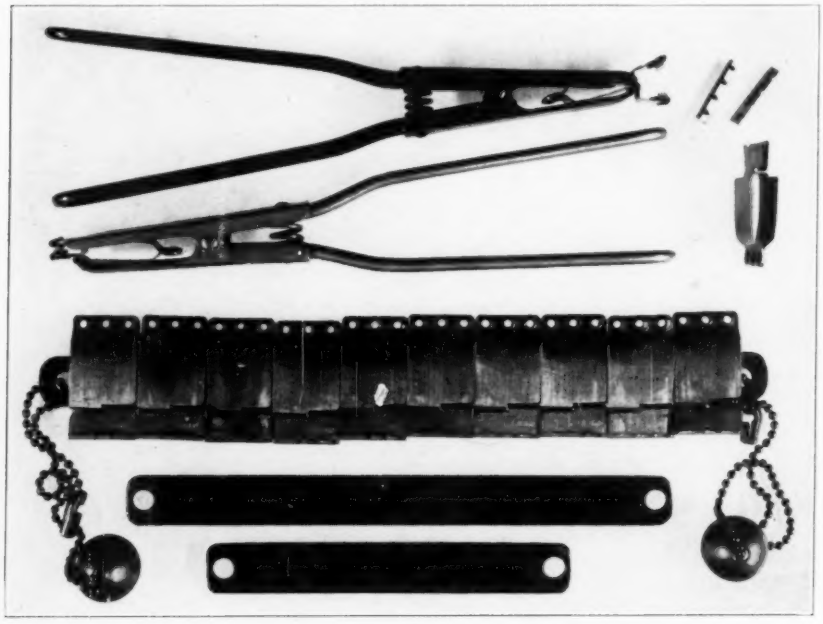


FIG. 1

The two instruments pictured are identical in make. The upper one shows a clip compressed in its distal portion and the lower one shows a clip being compressed medially, *i. e.*, close to the teeth. This is done to insure the teeth biting well into the skin and towel. They are removed by compressing the distal end of the clip. The removable teeth and clip are shown at the right-hand side of the illustration. Ten of them are shown at the lower portion of the picture with a metal rod and weights. Two additional rods of different lengths are shown in the lower part of the illustration.

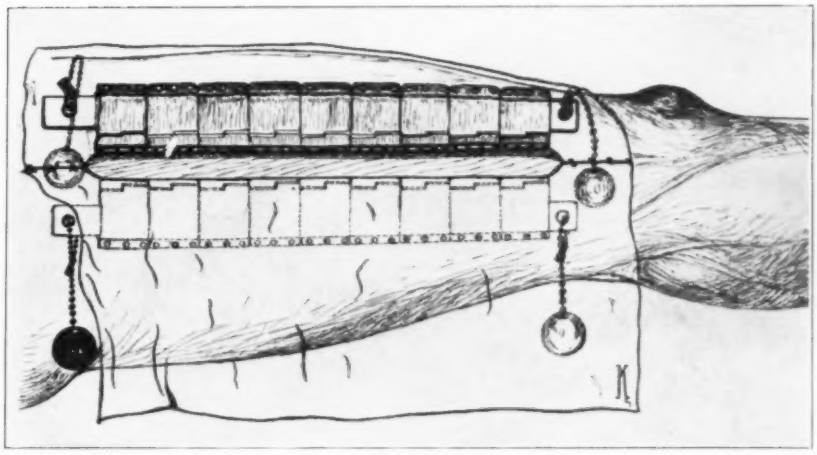


FIG. 2

Sketch of the clips in actual use in a leg-lengthening operation. The towels are pictured as if made of a transparent material. Details of the lower row of clips are not shown in order to simplify the drawing. Note that the metal balls are allowed to fall over both the medial and lateral sides of the leg. These provide even traction on the skin edges. The two towels are held together beyond the incision by Mischel clips.

suspended over either side of the incision (The lengths of the chains can be adjusted to suit the individual case) and serve to exert an even traction all along the wound. Any desired number of clips may be used, varying with the length of the incision in each particular case.

When rods of suitable length have been slipped into the middle of the clips, the clips and bars are turned backward as a unit (See Figure 2). Eversion of the skin edge is thus produced and a very complete isolation of the skin edges obtained. We have found them very helpful in retracting the skin edges during the operation and also in approximating the skin in suturing the wound.

These clips can be applied a great deal faster than Mischel clips or any other type with which we are familiar. In the illustration the towels are drawn as though made of transparent material in order to show the position of the clips, bars, and metal weights. Removal of the skin clips is equally simple. The metal bars are first pulled out; then, by means of the instrument shown in Figure 1, successive clips are removed.

This type of combined skin clip and retractor is reported because of its efficiency, simplicity, rapidity of application, and its relative inexpensiveness. The replaceable teeth are, as far as we know, a unique feature. This enables one to change them frequently at very little cost.

The writer wishes to acknowledge his indebtedness to Mr. Gus Tornsjo, Chief Technician, University of Missouri, for his help in the development of these special instruments.

CHOICE OF POSITION OF AXIS OF KNEE APPARATUS

BY JOHN JOSEPH NUTT, M.D., F.A.C.S., NEW YORK, N. Y.

In his admirable article on Flexion Contraction of the Knee in the July issue of *The Journal* (XIV, 618), Dr. Kulowski makes the statement: "It is absolutely essential that the joint remains the axis of motion of the system" (of the mechanical apparatus). This is difficult to accomplish in any joint, and in a compound joint well nigh impossible. It seems to me much safer to avoid the danger of interarticular pressure by moving the joint of the apparatus forward so as to have traction exerted on all the structures of the knee at the same time that extension is being forced.

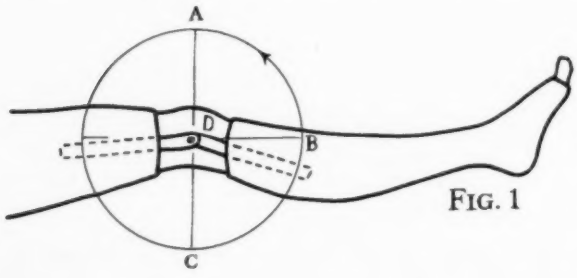


FIG. 1

This is easily done by continuing the lateral bars in elliptical curves and jointing them where they meet—in the horizontal plane of the anatomical axis. Figure 1 shows the direction of the movement about the axis of the apparatus in the above cited article. It is evident that in the quadrant BDC the movement is downward as well as forward, while in the quadrant ADB the movement is upward as well as forward. By changing the axis of rotation, D, to a point anterior to the knee, as in Figure 2, we have all the knee structures in the quadrant BDC and all the force exerted in a downward and forward direction with no danger of interarticular pressure.

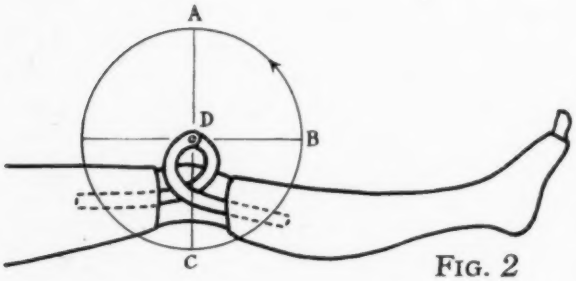


FIG. 2

In children, where the lever arms are short, it may be necessary for the bars to pass each other twice in order that their joint may be brought close to the anterior part of the knee.

A SANDAL FOR THE PREVENTION OF FOOT-DROP FOR USE WITH TRACTION-SUSPENSION APPARATUS *

BY CORNELIUS J. KRAISSL, M.D., NEW YORK, N. Y.

The use of a light-weight leather sandal, designed by the writer, has obviated many of the annoyances heretofore experienced with the adhesive, "mole skin", or light plaster formerly used to hold the foot in slight dorsiflexion for the prevention of foot-drop in cases requiring traction-suspension apparatus.

The sandal consists of four main pieces of leather as indicated in the diagram. The sole is pliable but more firm than the other parts. It is extended well beyond the toes and an elongated strip is left for fastening a ring to which the suspension cord will be attached. The heel piece is made of very soft, seamless leather, preferably lined with chamois, and is cut to fit the heel snugly. It is fastened over the dorsum of the foot with laces. A chamois tongue is attached just inside of the eyelets for the purpose of protecting the skin. Two wide, soft leather bands are secured to the front of the sandal and are laced in similar manner across the

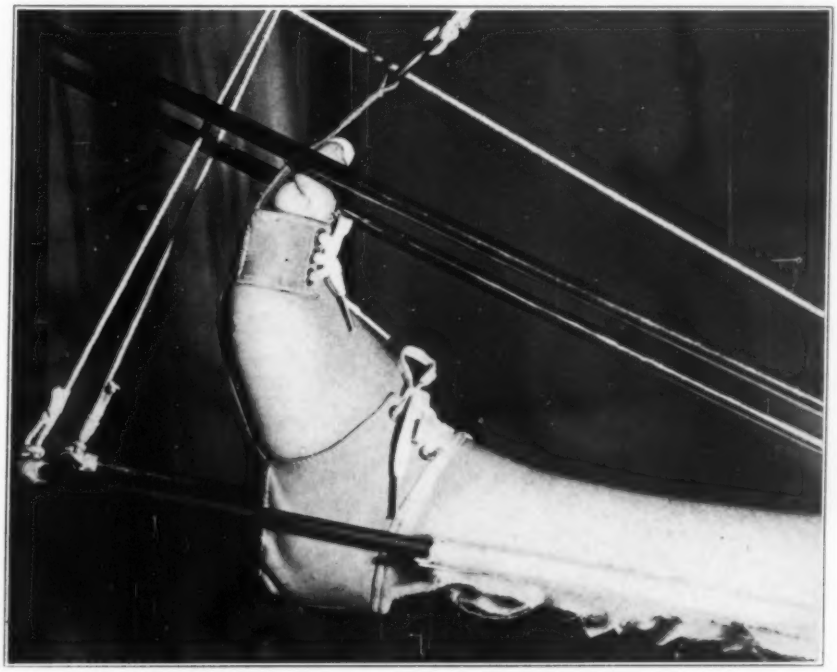


FIG. 1

Lateral view.

* From the Fracture Service, Presbyterian Hospital in the City of New York.

metatarsal region. The skin here is also protected by a similar chamois tongue. These pieces are sewed to the sole or may be laced to it by a leather thong if small holes are punched along corresponding margins.

Sandals, which are constructed in the three sizes indicated at the left of the diagram, will adapt themselves to nearly all sizes and shapes of feet and may be used interchangeably on either foot. Variations in the design, however, may prove to be of advantage where the foot shows some abnormality,—such as exostoses, requiring a wider sole piece, or a slanting heel, necessitating seams in the side of the heel piece. Lacing the heel piece on the side may insure a more perfect fit in some cases where there is a very marked curve of the heel toward the tendo achillis.

This type of appliance has proved more satisfactory than other methods of foot support for use with traction-suspension because of the following features:

(1). The increasing use of pin traction in the treatment of fractures, associated with early and continued active motion, com-

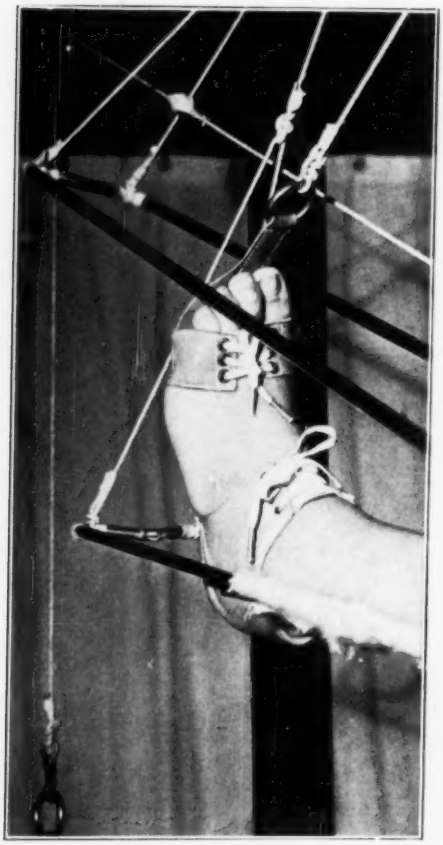


FIG. 2
Dorsal view.

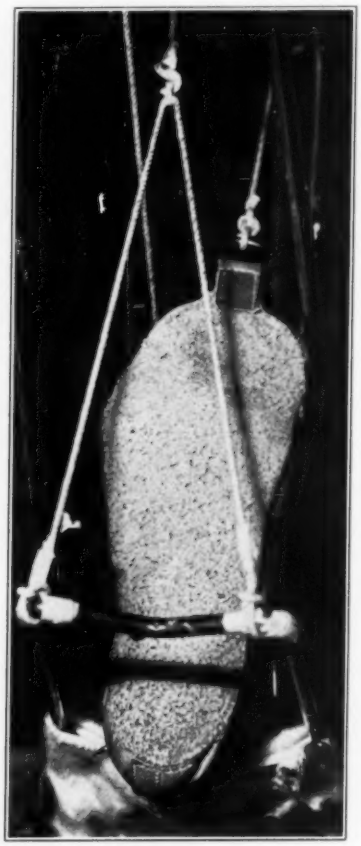


FIG. 3
Plantar view.

Small Size	
AB	26 cm.
CD	9 cm.
EF	6 cm.
GH	24 cm.
IJ	4 cm.
KL	4 cm.

Medium Size	
AB	29 cm.
CD	10 cm.
EF	7 cm.
GH	28 cm.
IJ	5 cm.
KL	4 cm.

Large Size	
AB	35 cm.
CD	12 cm.
EF	8 cm.
GH	34 cm.
IJ	7 cm.
KL	6 cm.

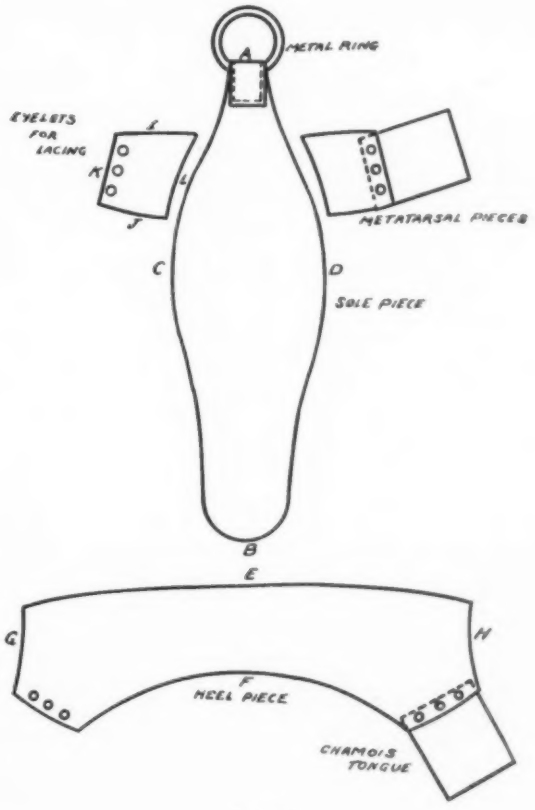


FIG. 4

Working drawing of a typical sandal.

bined with physiotherapy, soon causes adhesive to loosen and require reapplication, and each reapplication of adhesive is more detrimental to the skin.

(2). The sandal may be removed by a nurse, the foot cleansed, and the sandal reapplied with perfect safety, insuring a healthy condition of the skin.

(3). The sandal is easily applied, and one is assured of its stability.

(4). The appliance may be used over long periods of time with minimum discomfort to the patient. The photographs were taken of the sandal being worn by a patient for a period of sixty days. She complained of practically no discomfort during this entire time.

(5). The sandals are easy to make. They may be supplied by a brace-maker at a cost of $2.50 apiece.

If expense is an item, the Occupational Therapy Department may prove to be a valuable adjunct. At the Presbyterian Hospital this department supplies the convalescent patients with the leather, patterns, and a few tools for punching holes and inserting the eyelets. In this way a perfectly satisfactory article has been produced for about sixty cents and in addition provides useful diversional therapy for these patients.

News Notes

Just as *The Journal* goes to press, word has been received of the death of Dr. Russell A. Hibbs in New York on September 16. A tribute to the service of Dr. Hibbs will appear in the January issue.

Word has also been received of the death of Dr. Nathaniel Allison at La Jolla, California, on August 30. Further notice concerning Dr. Allison will be published in the next number of *The Journal*.

With deep regret *The Journal* announces the death of Docent Dr. Otakar Schulz of Prague, who died on June 4. Dr. Schulz was President of the Czechoslovakian Orthopaedic Society, Medical Director of the Jedlička Institution for the care of crippled children, and one of the outstanding orthopaedic surgeons of his country.

The Annual Roll Call of the American Red Cross to enroll members for 1933 will be held from Armistice Day to Thanksgiving Day, November 11 to 24.

Docent Dr. Zahradníček has been made head of the Orthopaedic Clinic of University Karlovy at Prague, succeeding Prof. Stanislav Tobiášek who died last November.

Dr. Robert V. Funston, formerly of Detroit, Michigan, is now located at University, Virginia, and has been made Professor of Orthopaedic Surgery of the University of Virginia at Charlottesville.

Dr. Vernon L. Hart, formerly of the Department of Surgery at the University Hospital, Ann Arbor, Michigan, has recently become associated with the Dayton Clinic, Dayton, Ohio. He is in charge of the Orthopaedic Service of the Clinic.

At the Congress of the **Deutsche Orthopädische Gesellschaft** at Mannheim, Dr. Arthur Steindler, President of the American Orthopaedic Association, was elected a Corresponding Member; and the Editor of *The Journal* was made an Honorary Member.

The good will and the assets of William Wood and Company of New York have been purchased by the Williams and Wilkins Company of Baltimore. William Wood and Company is one of the oldest medical publishing houses in the country, having been established in 1804 by Samuel Wood.

A symposium on dental caries was held in Pittsburgh, Pennsylvania, on June 23, under the auspices of the International Association for Dental Research. The proceedings of this symposium were published in the August issue of the *Journal of Dental Research*, and reprints may be obtained upon request to the Mellon Institute of Industrial Research, Pittsburgh.

The Aid Association of the **Philadelphia County Medical Society** is establishing a Perpetual Memorial Fund in honor of Dr. John B. Deaver. The income from this fund will be used to afford aid to needy physicians and their families. Those who desire to contribute to such a fund should communicate with Dr. Francis Heed Adler, Secretary, 313 South 17th Street, Philadelphia, Pa.

At the Executive Committee Meeting of the **British Orthopaedic Association,** held June 21, the following were elected Associate Members:

Grant Massie, Esq., 55, Wimpole Street, London, W. 1.
Philip Wiles, Esq., 90a, Harley Street, London, W. 1.
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E. N. Wardle, Esq., Sheildaig, Oakfield Road, Heswall, Cheshire.

The Second Congress of the International Society of Orthopaedic Surgery will be held in London July 19 to 22, 1933. The officers are:

President:	Prof. Nové-Josserand, Lyons, France.
Vice-Presidents:	Prof. Murk Jansen, Leiden, Holland.
	Prof. Gocht, Berlin, Germany.
	Prof. Vittorio Putti, Bologna, Italy.
Secretary General:	Dr. Delchef, Brussels, Belgium.
Secretary:	Mr. Harry Platt, Manchester, England.
Treasurer:	Prof. Maffei, Brussels, Belgium.

The sessions will be held at the Royal Society of Medicine and the program includes the following:

Wednesday, July 19, 1933.

2 P.M. Reunion of the International Committee.
4.30 P.M. General Assembly.
8.30 P.M. Reception by the President.

Thursday, July 20, 1933.

9.45 A.M. Presidential Address.
10.30 A.M. Mechanism of Articular Movements in General.
Prof. H. von Baeyer, Heidelberg, Germany.
Prof. Riccardo Dalla Vedova, Rome, Italy.
Prof. Richard Scherb, Zürich, Switzerland.
2.30 to 5.30 P.M. Operative Clinics.
6.30 P.M. Reception by the Royal College of Surgeons.

Friday, July 21, 1933.

9 A.M. Treatment of Tuberculosis of the Hip.
Prof. Philipp Erlacher, Graz, Austria.
Dr. Maffei, Brussels, Belgium.
Dr. Melvin S. Henderson, Rochester, Minnesota, U. S. A.
Dr. E. Sorrel, Paris, France.
2.30 P.M. to 5.30 P.M. Operative Clinics.
7.45 P.M. Banquet.

Saturday, July 22, 1933.

2 P.M. Visit to the Orthopaedic Hospital of Alton.

The British Orthopaedic Association had a one-day meeting in London on July 27, 1932, under the presidency of Mr. A. S. Blundell Bankart.

In the morning, Dr. Max Böhm, of Berlin, read a paper on "Infantile Deformities". Ten years' research work had convinced him that the common deformities—such as pes valgus, pes planus, genu varum, genu valgum, genu recurvatum—are not due, according to popular belief, to static disorders, but to an arrested development; the deformity being, in every case, the condition normally met with in the foetus and in the anthropoid.

Mr. Blundell Bankart gave an address on "Chronic Tuberculous Osteomyelitis of the Ilium, Involving the Hip Joint". He said he had been endeavoring, by means of a formidable operation, to remove all the diseased area; this implied a resection of the head

and part of the neck of the femur, of the acetabulum, and of the acetabular-bearing portion of the ilium. The result is a painless, stable pseudarthrosis.

Prof. Vittorio Putti, of Bologna, Italy, read a paper on the "Abduction Method of Treating Congenital Dislocation of the Hip in Young Infants", and summarized his experiences with the method.

The afternoon session was devoted to a clinical demonstration by the President, Mr. Blundell Bunkhart.

The Twenty-Seventh Congress of the Deutsche Orthopädische Gesellschaft was held in Mannheim on September 5, 6, and 7, under the presidency of Dr. Adolf Stoffel, with an attendance of about 450 members and guests. In accordance with the custom of the Society the preceding evening was devoted to the *Begrüssung Abend*, allowing to the members the opportunity of meeting together before the opening of the scientific part of the program.

In the scientific meetings, four principal subjects were considered,—Fracture of the Neck of the Femur, Operation for Remodelling the Acetabulum, Internal Injuries to the Knee Joint, and Treatment of Malunited and Ununited Fractures.

The papers and discussions on the first subject were directed mainly toward the question of the treatment, either by fixation in plaster-of-Paris, or by operation. The concurrence of opinions was distinctly in favor of the treatment by plaster, and the method of Whitman was generally used. In the treatment of the old ununited cases, the operative procedure by means of the bone graft was preferred by the large majority of the speakers; but one used a metal peg. The discussion distinctly brought out the need of long continued treatment and observation because of the danger of late necrosis and subsequent yielding at the point of reunion. Observation over a period of eighteen months was considered advisable.

In the operation for remodelling the acetabulum, the breaking down of a portion of the outer table of the acetabular cavity, and the roofing operation were mainly considered, and, in general, the producing of a projecting area of bone by some one of the various methods for impingement of the head of the femur was preferred. It was also brought out that, in establishing some form of bone impingement, it is not sufficient to rely alone upon the bone projection; but, to insure security, it is necessary to transplant downward the trochanter with its muscular attachments. Mobilization must begin early,—at least within two weeks.

On the subject of internal injuries to the knee joint, rupture of the crucial ligaments, and injury to the meniscus were the main topics considered. One remarkable series of sixty-nine cases, operated upon by one surgeon and with a satisfactory percentage of successful results, was presented. In the discussion of the methods of operation for repair of the crucial ligament, several cases of suture of the anterior to the posterior ligament with good results were reported. The opinions were equally divided between the removal of the entire meniscus and of the injured portion only. The incision most frequently used was the long longitudinal incision of Payr. The time allowed for full convalescence varied very considerably among the different surgeons.

In the part of the program devoted to the subject of malunited and ununited fractures a large number of the various types and cases were shown, and the individual methods and techniques of dealing with these were demonstrated. The uniformity of the problem to all surgeons dealing with traumative surgical conditions was evident. The method—sometimes referred to as the American system—of dealing with the compensation of the industrial cases by cash settlement was advocated by some surgeons, but also it was emphasized that the necessary operation for the special case should precede the settlement. The discussion on the social aspect also showed that the same difficulties are encountered by all surgeons and in all countries.

The next meeting will be held in 1933 in Leipzig, under the presidency of Dr. Schede.

Current Literature

MANIPULATIVE SURGERY. By A. S. Blundell Bankart, M.A., M.Ch. (Cantab.), F.R.C.S., London, Constable and Company, Ltd., 1932. 7/6 net.

In presenting this small volume on manipulative surgery, Bankart has rendered a real service. This country is overpopulated with those ready to capitalize the failures of surgeons to recognize the value of this branch of their therapeutic armamentorium. The "natural bone-setter" is by no means the only one to profit by the failure of the medical profession to cultivate this field. Physicians should make themselves acquainted with the lesions amenable to this line of treatment as well as with the technique of their management.

In the introductory chapter is a clear presentation of what constitutes a sprain and what are the physiological indications for its treatment. A few paragraphs—the most significant in the chapter—are devoted to Sherrington's studies on what he terms "postural" muscular action and "phasic" muscular action, upon an understanding and acceptance of which hinges the whole art of manipulative procedure. This part of the discussion should be thoroughly mastered. Very sound advice is given as to the selection of cases for manipulation. The reasons for failure are outlined and suggestions offered as to the pathological features of the chronic non-tuberculous arthritides which are sane and sound. Emphasis is laid on the fact that, unless one is prepared to carry out what is erroneously termed the "after treatment", one has no right to undertake the initial manipulation. The importance of full surgical anaesthesia is urged.

In the chapter on the foot is a clear presentation of the author's ideas of the causation of "weak" or "flat-foot" and the type of treatment appropriate to the different grades of this trouble. It is an admirable discussion of the subject which is particularly valuable to American orthopaedic surgeons committed to the get-relief-quickly methods of treatment. "Anterior metatarsalgia" or,—as we know it here in America—"Morton's toe", is regarded as a "traumatic arthritis" of some of the outer metatarsophalangeal joints, which is a theory having less to support it than Morton's explanation does.

In a chapter on the knee, "internal derangements" of this joint are well discussed and the application of manipulative measures for their treatment is outlined. Among other subjects discussed he gives a paragraph to the synovial folds in the anterior part of the joint that are occasionally pinched, causing symptoms not unlike semilunar cartilage displacements.

A short discussion of hip manipulation leads up to chapters on "Sprains of Muscles and Tendons in the Lower Extremity", "The Spine and Pelvis", "The Fingers, Hand, and Wrist", "The Elbow", "The Shoulder", and a chapter on "Bone-Setting and Osteopathy".

A chapter summarizing what has gone before and an appendix upon the sub-astragaloid and mediotarsal joints closes this most instructive contribution to our knowledge of manipulative surgery, an appreciation of which will go far to counteract the influence of the "cults".

RÖNTGENDIAGNOSTIK DER KNOCHENVERLETZUNGEN. By Dr. Fritz Schnek. Vienna, Wilhelm Maudrich, 1932.

This book, consisting of 333 pages and containing 389 illustrations, is the result of a wide experience of the author in the treatment of bone injuries, under the direction of Dr. Lorenz Böhler. The latter, in a foreword, very appropriately emphasizes the need of such a work. In producing this volume the author has set out to answer a

number of questions pertaining to diagnosis and treatment of fractures. Among these are the following: Is a displacement present which demands a correction of position? When is a control examination to be undertaken? When the fragments are displaced, is the displacement which will eventually be present significant for function? Is the reduction anatomically correct? In what position has healing occurred? What can be said regarding the length of time required for healing? Is the formation of callus progressing normally? Has sufficient bony union taken place to permit weight-bearing? Are changes present in the bone or soft tissues, which give any indication of future function? Is there a disturbance of callus formation, or a pseudarthrosis?

In answering these and many other questions relative to bone injuries, several chapters are devoted to general considerations of diagnosis. Thus there are discussions on problems of the roentgen examination, technical procedures, the observation and analysis of the roentgenogram, the control examination, the diagnosis of the fracture, normal callus formation, disturbance of callus formation, bone atrophy in healing of fractures, and arthritis deformans.

In the special portion of this book are found descriptions of the various types of fractures occurring in the upper extremity, the lower extremity, the skull, and the spine.

The reader will be impressed with the simple, but thorough and systematic style of writing employed by the author in presenting his subject. This is supplemented amply by illustrations which are helpful and instructive. The material contained in this volume is written entirely from the experience of the author and includes only a few references to other works. Attention is called to many points which are easily overlooked. The conviction and authority with which the author expresses himself are undoubtedly the results of the unusual opportunities which he has had to observe bone injuries. This book will be a valuable asset to the roentgenologist and to the surgeon. It may be stated that some portions of this work are somewhat mystifying, as a result of the particular type of treatment employed, and for this reason the principles which are advocated will have a stronger appeal to the reader who is familiar with the author's therapeutic methods.

ORTHOPAEDIC SURGERY. By Walter Mercer, M.B., Ch.B., F.R.C.S. (Edin.), F.R.S. (Edin.). With a Foreword by John Fraser, M.C., M.D., Ch.M., F.R.C.S.E. London, Edward Arnold and Co., 1932. 32/6 net.

In this new Orthopaedic Surgery of Mercer's, the publishers have given us a well printed, single-volume work of 659 pages, thoroughly indexed and accompanied by a classified bibliography at the end of the text and not encumbering it. The style is clear and the illustrations are for the most part excellent, though some of the x-ray reproductions are not as good as is desirable. The entire field of orthopaedic surgery is covered in a way which will serve the needs of a general practitioner or a surgeon admirably. It has been written by a general surgeon of wide experience who has found his particular interest in the problems of the orthopaedic specialist. Such is the proper evolution of a specialist in any surgical branch and perhaps this is particularly true of the field with which this volume deals.

ARTHRITIS DEFORMANS UND CHRONISCHE GELENKKRANKHEITEN. By Prof. Dr. Hans Burckhardt. Neue Deutsche Chirurgie, LII. Edited by H. Küttner. Stuttgart, Ferdinand Enke, 1932. 55.50 marks.

In this work the author has undertaken the task of demonstrating the different features of arthritis deformans as a clinical entity, and also as a disease picture playing an important rôle in the course of many chronic joint ailments. From his conception of arthritis deformans, the author mentions the characteristics of this condition and discusses it in its relation to the joint changes occurring in various other joint diseases.

Beginning with a description of the anatomical and physiological features of joints, the author proceeds to a consideration of all the component structures in their pathological state. This is followed by a detailed description of the histological characteristics of all the tissues involved in arthritis deformans. Among other conditions to be discussed are joint mice, injuries to the meniscus of the knee, and chondropathy. Attention is then directed to the group of epiphyseomalacias, including Perthes' osteochondritis deformans juvenilis, Köhler's disease of the heads of the metatarsals, Kienböck's disease of the carpal lunate, and Köhler's disease of the tarsal scaphoid. There are, further, discussions of coxa vara, coxa valga, fracture of the neck of the femur, regenerative processes (pseudarthrosis, nearthrosis, and arthroplasty), neuropathic joint diseases, hemophilia, and chondromatosis.

The most important portions of this work are, of course, the descriptions of articular rheumatism (polyarthritis rheumatica) and arthritis deformans. These two conditions are treated separately, and in a detailed and thorough manner. Among the other chronic joint ailments which are mentioned and discussed at varying length are the arthritides associated with gonorrhoea, syphilis, tuberculosis, leprosy, gout, ochronosis, psoriasis, Raynaud's disease, Gaucher's disease, osteophytosis and osteitis deformans.

In all the more important conditions, there is a detailed discussion of the etiology, pathology, symptomatology, diagnosis, and treatment. Description of treatment is, however, frequently restricted to a brief mention of the indications, the technical details being omitted. One chapter, devoted to treatment of joint ailments, enumerates the different methods, local and general, of conservative therapy, and describes briefly several operative procedures which have been found to be efficacious in joint disease.

The bibliography comprises thirty-eight pages and in this the references are more complete than is usually the case. The illustrations, seventy in number, are clear, instructive, and well chosen, but might be more numerous.

The most important and impressive feature of this book is the thoroughness shown in the description of pathological tissues. This work should be of real assistance to any student of chronic joint diseases.

FUNGOUS DISEASES. A Clinico-Mycological Text. By Harry P. Jacobson, M.D. (With introductions by Jay Frank Schamberg, M.D. and Howard Morrow, M.D.) Springfield, Illinois, Charles C. Thomas, 1932. $5.50.

The aim of the author has been to "make available to medical students and practitioners a comprehensive, concise, and readable discussion of the subject of clinical mycology" and he has succeeded admirably. The book considers briefly the elements of mycology with enough of the fundamentals to enable a student without the expenditure of unnecessary time to begin and continue intelligently the study of fungous diseases. It considers the dermatomycoses, about which so much is being written, and follows with discussions of the fungous diseases which, in addition to the skin, may affect the viscera, bones, and cerebrospinal system. Of these it describes and discusses sporotrichosis, blastomycosis, actinomycosis, and coccidioides or so called California disease (which is considerably more widespread than this name would imply. All of these may be serious and intractable infections of interest to those doing surgery as well as to dermatologists and internists.

A feature which adds to the pleasure and profit in reading this book is the historical summary with which each chapter is provided, and there is an excellent bibliography appended.

Such criticism as the book will have may fairly come, we believe, from the mycologists. The whole subject of classification in medical mycology is in a rather chaotic state at the present time and simplification is a necessity. Such classifications as the author has adopted do not take advantage of simplifications which are already

sufficiently well founded and which should at least be included in a book of this sort. Such omissions can be included in future editions, which will undoubtedly be called for. There is no similar book in English and undoubtedly it will be much used, particularly by medical students.

The volume itself is an excellent example of good book-making and the illustrations are numerous and illuminating.

FRACTURES. By Meurice Sinclair, C.M.G., M.B., B.Ch. (Edin.). With an Introduction by Sir Robert Jones, Bt., K.B.E., C.B., F.R.C.S. London, Constable and Company Ltd., 1931. 24 shillings net.

Sir Robert Jones writes an introduction calling attention to the memorable service of Major Sinclair at the front in the Great War. Major Sinclair conducted a Fracture Hospital and the results of treatment at this hospital were a great tribute to his devotion and ability.

The book is in two parts and contains an exposition of Major Sinclair's own technique and experience during the past sixteen years. General Considerations occupy 225 pages and Individual Fractures, 312 pages.

The author believes that three cardinal principles govern the treatment of every fracture: (1) prevention of further injury; (2) replacement of damaged parts into normal axial alignment; (3) restoration of function. The technique followed by Major Sinclair is described and it is rightfully insisted that this technique must be faithfully followed if results are to be obtained by it. The Sinclair skate, the malleolar caliper, the supracalcaneal stirrup, the universal suspension frame, the net bed, the Thomas splint and its various attachments, the arm splint, the abduction cushion, the forearm splint, the racket splint are described. These have all been devised by Major Sinclair. He prefers to hold a fracture by wire when possible instead of by a steel plate and screws. Immobilization, extension, and suspension are insisted upon and are to be employed when indicated.

The value of this book lies in the presentation of Major Sinclair's personal experiences in a very extensive practice in treating fractures. The book is a clear, concise statement of one man's treatment of fractures, together with the fundamental principles involved. Argumentative excursions are absent.

KÜNSTLICHE GLIEDER. HEFT 1. UNTERE EXTREMITÄTEN. (Artificial Limbs. Volume I. The Lower Extremities.) By Dr. Friedrich Mommsen and Dr. Kurt Büchert. Stuttgart, Ferdinand Enke (Beilageheft zur *Ztscher. f. Orthop. Chir.* LVI), 1932. 8 marks.

A wealth of ingenious and new ideas have been developed in the construction of artificial limbs since the World War. Samples, models, and drawings of prostheses have been collected at the Oskar-Helene-Heim in Berlin. With this material as a nucleus, representative artificial legs from all of the world and particularly Germany are presented in this first volume of one hundred and twenty pages. Detailed drawings of sixty different types are given, with brief mention of their outstanding features. There are legs so simple that they sacrifice grace of locomotion, and others so complicated that they are discarded as cumbersome. But here is a collection of applied mechanical principles that will furnish inspiration to any surgeon or limb-maker who is looking for a different way of solving an unusual problem.

THE LABORATORY IN SURGICAL PRACTICE. By E. C. Dodds, M.V.O., M.D., and Lionel E. H. Whitby, C.V.O., M.D. (Camb.), M.R.C.P. (London), D.P.H. London, Constable and Company, Ltd., 1931. 8/6 net.

The need for preoperative study of prospective surgical cases cannot have too

much emphasis. Hence a test that is practical for the surgeon, in that it clearly defines the need for routine valuation of operative risks, even where they seem good on the surface, is a valuable book. The minimal hemoglobin index and the red count which is a contra-indication for operative work should be borne in mind. Leukocytosis, its limits, and the causes for its variation, as well as the condition in which its determination is of special importance, must be considered, and so on with sputum, feces, urine, infections, and coagulation time, etc. So much help is obtained these days from blood transfusions that a full chapter is devoted to methods of determining the compatibility of donor and recipient and the interpretation of the agglutinative reactions. Serum therapy as an adjunct of operative surgery and the employment of vaccines, bacteriophages, and serums, and the ways of avoiding allergic reactions receive adequate consideration. A chapter on the association of pregnancy and diseases—such as diabetes, jaundice, osteitis fibrosa cystica, etc.—in patients upon whom some postponable operation is contemplated receives merited discussion. Two chapters are allotted to the clinical examination of the urine, stressing the importance of bedside investigations and pointing out the value of further laboratory study where certain specific matters require a solution. Questions of the integrity of renal function are important.

In describing tests appropriate to the investigation of gastro-intestinal diseases, a full discussion of the Ewald and fractional test meals is given. Also the value of certain of these tests in determining the potency of gastro-enterostomy stomata is pointed out. The diagnosis of certain diseases of the pancreas from other abdominal conditions may be helped by a study of the digestion of starches by the pancreatic diastase, which is normally poured into the intestine when the pancreatic duct is not obstructed. In respect to tests of liver function, the author passes over the very numerous tests described in the literature and cites two relating to the determination of the icterus index and the global functioning capacity of the liver. Intravenous cholecystography is described as it has been developed; its uses and dangers indicated. The fact that four-fifths of the liver may be destroyed without causing any symptoms, but if the other fifth is taken away, violent convulsions occur unless intravenous glucose is administered, makes it appear that tests of functioning capacity are of little value in estimating the amount of liver tissue destroyed. A chapter is devoted to a discussion of the value of basal metabolism as applied to the study of thyroid cases. The last three chapters are concerned with the significance of exudates and transudates in the bacteriological, chemical, and biochemical tests of value in the study of effusions in the chest, abdomen, and articular cavities, together with detailed descriptions of these various tests and the technique of their application, especially in the case of blood-urea and alkali reserve.

Die Unspezifischen Chronischen Erkrankungen der Wirbelsäule. By Prof. Dr. Hans Burckhardt. Stuttgart, Ferdinand Enke, 1932. 50 marks.

This booklet consists of seventy-four pages and contains twenty-two illustrations. It was originally intended to form a part of the volume on "Arthritis Deformans und Chronische Gelenkkrankheiten" but, for various reasons, has been published as a separate work. The subjects under consideration in this volume are anatomy of the spine, Schmorl's "Knorpelknötchen," Scheuermann's disease (round back), fish vertebrae, degeneration of the intervertebral discs, Calvé's disease, fracture of the spine, Kümmell's disease, spondylitis deformans, spondylitis ankylopoetica, rheumatic spondylitis, inflammations, neuropathies, and spondylolisthesis. These subjects are discussed in the same manner as the diseases in the volume mentioned above. The material is limited to a description of conditions which are related to arthritis deformans or to chronic joint ailments.

THE SIGN OF BABINSKI. A STUDY OF THE EVOLUTION OF CORTICAL DOMINANCE IN PRIMATES. By John F. Fulton and Allen D. Keller. Springfield, Illinois, Charles C. Thomas, 1932. $5.00.

This monograph deals with the nature and significance of the sign of Babinski from a study of this and other pathological reflexes in the higher primates. In the order of cortical development the animals used were the monkey, baboon, gibbon, and chimpanzee. In the lower vertebrates, as the dog and cat, only crude homologues of the normal plantar and Babinski reflexes were found, and the authors hold that the Babinski phenomenon is essentially a problem of the primate foot. In the higher primates used the normal plantar reflexes were found absent or predominantly flexor in type.

In the experimental studies the animals were subjected to damage to some portion of the pyramidal pathways, such as complete cord transection, cord semisection, ablation of one or both foot areas, and complete removal of a single hemisphere.

In the monkey complete cord transection at first lumbar segment caused "spinal shock" or depression lasting several days. Some sort of plantar flexion was the first reflex to return, but nothing resembling a Babinski reflex occurred. Lateral cord semisection at the first lumbar segment caused a well marked Babinski response to strong stimulation on the sixteenth day.

Ablation of a part or a complete removal of an entire hemisphere caused a poor Babinski or none at all, respectively. This suggests that the pyramidal system is less completely dominant than in the higher forms. In the baboon these same procedures caused a Babinski response. The gibbon showed even more evidence of cortical dominance, and, finally, in the chimpanzee, whose motor cortex is nearer that of man than is that of any other infrahuman primate except the gorilla, the above procedures caused more profound reactions than in the lower orders.

A chapter is then given to a general discussion of the evolution of cortical dominance in man, and in the appendices the experimental methods involving the use of barbituric derivatives for anaesthesia and electrosurgical technique are described.

The studies represent a new approach to a large and most important subject, and the development of the plan should yield valuable results.

The Journal wishes to acknowledge the receipt of the following publications sent to the Editorial Department:

Norsk Magasin for Laegevidenskapen. Oslo, Norway, Vol. XCIII, Nos. 7, 8, and 9, July, August, and September 1932.

Slovanský Sborník Ortopedický. Brno, Czechoslovakia, Vol. VII, Nos. 2, 3, and 4, 1932.

Revista de la Facultad de Medicina. Bogotá, Colombia, Vol. I, Nos. 1, 2, and 3, June, July, and August 1932.

The Southern Surgeon. Vol. I, No. 2, July 1932.

United Fruit Company, Medical Department, Twentieth Annual Report, 1931. Boston, 1932.

Bulletin of the National Tuberculosis Association. Vol. XVIII, Nos. 8 and 9, August and September 1932.

The Journal of the Indian Medical Association. Calcutta, Vol. I, Nos. 8, 9, and 10, April, May, and June 1932.

Journal de Médecine de Bordeaux et du Sud-Ouest. Bordeaux, Vol. CIX, No. 13, May 10, 1932.

Life and Death in the Medical Profession. By Frederick L. Hoffman, LL.D. Newark, Prudential Press, 1932.

Announcements, The University of Chicago, The Medical Schools Number. Chicago, The University of Chicago Press, Vol. XXXII, No. 21, 1932.

HYPERPARATHYROIDISM AND OSTEITIS FIBROSA GENERALISATA. John Hellström. *Acta Chir. Scandinavica*, LXIX, 237, 1932.

A critical survey of the literature of hyperparathyroidism, with tabulation of thirty-five cases in which parathyroids had been removed, strengthens the opinion that hyperfunction of these glands is one of the causes of osteitis fibrosa generalisata. In thirty-three cases actual enlargement of one or more glands was found. The results with parathyroidectomy were better, on the whole, than with other methods of treatment. In view of the occurrence of spontaneous remissions, the cases which had been under observation for only a short time were not accepted as permanently improved.

Three personal cases are reported in detail. In one an adenoma was removed with complete relief of symptoms. In the second there was temporary relief from the extirpation of an adenoma the size of a walnut; recurrent symptoms were entirely relieved by the removal of a second adenoma the same size as the first. In a third case with coincident hyperthyroidism, deep x-ray therapy resulted in remarkable general improvement and healing of the bones, although the serum calcium remained high. Reproductions of x-rays of the three cases before and after treatment are included.—*W. P. Blount, M.D., Milwaukee, Wisconsin.*

OSTEOCHONDRITIS DISSECANS CAPITULI RADII. *Aage Nielsen. Acta Chir. Scandinavica*, LXIX, 305, 1932.

Osteochondritis dissecans of the right radial head is reported in three men, sixteen to twenty-two years old. Trauma was not a factor, and by none of the cases was the etiology clarified. With the forearm supinated the lesion was uniformly of the portion next to the ulna. Pain, weakness, limitation of motion, and atrophy were the chief symptoms. The loose pieces removed at operation were exactly similar to the ones removed in cases of osteochondritis of the humeral or femoral condyles.—*W. P. Blount, M.D., Milwaukee, Wisconsin.*

MULTIPLE MYELOMA OF BONE: REPORT OF TWO CASES WITH REMARKS ON HISTOGENESIS. Harold W. Williams. *Am. J. Cancer*, XVI, 540, 1932.

The author reported two cases of multiple myeloma with numerous photomicrographs. He suggested that the bone resorption, inevitably present, may be a key to the histogenesis of this tumor.

After reviewing current theories as to the origin of the tumor he presented evidence for the belief that the osteoblast is the cell of origin.—*Grantley W. Taylor, M.D., Boston, Mass.*

CHORDOMA DORSALIS OF THE CERVICAL SPINE. Clarence I. Owen, Lynn N. Hershey, and Elisha S. Gurdjian. *Am. J. Cancer*, XVI, 830, July 1932.

The authors describe with photomicrographs and roentgenograms one case of chordoma of the cervical spine. They present also brief summaries of eight other cases which they were able to collect from the literature. On the basis of x-ray examination, the diagnosis has usually been tuberculosis of the cervical spine, although in their own case metastatic carcinoma was suspected. The symptomatology occasionally involves tenderness in the cervical spine, and frequently neurological symptoms, and paralyses. They suggested that in case of tuberculosis of the spine in which operation is performed, a biopsy should be done. The tumors are apparently not susceptible to radiation therapy.—*Grantley W. Taylor, M.D., Boston, Mass.*

ABNORMALITIES OF THE VERTEBRAL BODY. William A. Evans. *Am. J. Roentgenol.*, XXVII, 801, June 1932.

This extremely timely and very excellent paper first takes up the normal variations peculiar to certain ages; these normal changes often lead to mistaken diagnosis

when they are not properly appreciated. Developmental anomalies are next discussed. Changes associated with nutritional disorders and disturbances of the endocrine glands are mentioned, and the importance of the early recognition of these conditions, the treatment of which may prevent scoliosis, is stressed.

Inflammatory changes—tuberculosis, syphilis, osteomyelitis, epiphysitis, osteochronditis and osteo-arthritis—are carefully differentiated. The spinal changes due to posture or occupation, and deformities secondary to intervertebral disc changes are discussed. Lastly, the spinal changes incident to constitutional disease and malignancy are given.

This paper is beautifully illustrated and is one of the best contributions that has appeared for some time.—*Edward S. Hatch, M.D., New Orleans, Louisiana.*

THE ROENTGEN SIGNS OF TUBERCULOSIS OF THE VERTEBRAL BODY. Howard P. Doub and Carl E. Badgley. *Am. J. Roentgenol.*, XXVII, 827, June 1932.

This paper correlates the characteristic roentgen pathology seen in the early spinal tuberculous lesions. Infection is by the hematogenous route. The question of cases originating primarily in the disc and by the lymphatic system are spoken of. Three types were found,—central and intervertebral articular and anterior.

The authors feel that spinal tuberculosis is devoid of symptoms until there is a collapse of the body and some involvement of the disc. Narrowing of the disc is the earliest and most constant roentgen sign in tuberculosis of the spine.—*Edward S. Hatch, M.D., New Orleans, Louisiana.*

DIE TIEFE SUBTROCHANTERE OSTEOTOMIE NACH SCHANZ BEI VERALTETER LUXATIO COXAE CONGENITA. (The Low Subtrochanteric Osteotomy of Schanz in Old Cases of Congenital Dislocation of the Hip.) Dahs und Schwarz. *Arch. f. Klin. Chir.*, CLXIX, 494, 1932.

Following a discussion of various methods of treatment employed in old cases of congenital dislocation of the hip, the authors made an analysis of forty-three patients in whom an end-result study was possible. Of these seventeen were unilateral, and twenty-six were bilateral dislocations. The Lorenz bifurcation operation was used in eight cases and the subtrochanteric osteotomy of Schanz in thirty-five cases. The latter method of treatment is preferred to any other form of palliative treatment. The analysis of their cases, both successes and failures, is very complete and instructive. The article contains reports of six typical cases.—*R. J. Dittrich, M.D., Fort Scott, Kansas.*

UNTERSUCHUNGEN ÜBER DIE VERÄNDERUNGEN AN DER GELENKKAPSEL UND IHRE BEZIEHUNGEN ZU DEN ERGÜSSEN DES KNIEGELENKS. (A Study of the Changes in the Joint Capsule and their Relations to Effusions of the Knee Joint.) Heinz Baumecker. *Arch. f. Klin. Chir.*, CLXX, 511, 1932.

From a study of the literature and his own investigations on the knee joint of man and animals, the author discusses the anatomy of this joint with reference to the physiological exchange of fluids. By the injection of dyestuffs and chemical methods, it was shown that an open communication between the joint cavity and the joint capsule does not exist.

By injection of sodium iodid into the knee joint, the process of absorption was studied. Sodium iodid, injected into the joint, could be demonstrated in the saliva of dogs in twenty-one minutes, and in the saliva of rabbits after fifteen minutes. Direct penetration through the isolated joint capsule was demonstrated by the injection of salicylic acid. In this a color reaction with iron chlorid was observed after six minutes.

With movement of the joint, the penetration of fluids through the capsule was hastened. Absorption was most rapid in the "zone of insertion".

On the basis of animal experiments and observations and investigations on the human knee joint, the important factors in traumatic effusions are considered. The microscopic changes of the synovia in traumatic injuries received special attention.

The degree of admixture of blood in traumatic effusion was dependent on the extent and the location of the injury to the synovia.

Investigations of the influence of nerves on the joint fluid led to a positive result only in case of periarterial sympathectomy. Following this operation, a vasodilatation was noted in the joint capsule and the absorption from the knee joint was hastened. An increased absorption could not be demonstrated after fourteen days.

The cause of recurrent effusion was traced back to changes in the synovial membrane.

Investigations of the healing of joint wounds showed that an interruption of continuity in the synovial membrane heals by formation of fibrous tissue. Regeneration in uncomplicated wounds was completed in two to three weeks. Joint wounds sutured with silk or catgut healed more slowly and showed a more intense inflammatory reaction. The inflammatory changes in silk sutures were less severe than in those of catgut.

It was shown experimentally that the synovial membrane, in case of para-articular inflammation, acts temporarily as a protection to the joint cavity. Absorption is more rapid from inflamed joints.

Ligation of the femoral vein was followed by effusion and hemorrhages of the synovia. Absorption was increased. The same changes were produced by immobilizing the thigh with a plaster cast.—*R. J. Dittrich, M.D., Fort Scott, Kansas.*

Die Körperhaltung bei Einseitiger Beinbelastung und ihre Änderung bei Ausfall der Hüftabductionsmuskeln. (Body Posture When Standing on One Leg and its Variation in Paralysis of the Hip Abductors.) H. Storck. *Arch. f. Orthop. u. Unfall-Chir.*, XXX, 299, 1931.

This paper is based on the observation of Gocht that patients with unilateral hip dislocation can improve their gait decidedly by carrying a weight in the hand of the affected side. Storck made similar observations on patients with unilateral paralysis of the hip abductors and explained the phenomenon by the construction of simple mechanical models. A patient who ordinarily would have to tilt the body twenty-five degrees to the left to maintain balance, when standing on the left leg, can hold the body almost erect when the left hand carries a weight of twenty kilograms.—*Leo Mayer, M.D., New York, N. Y.*

Die Angeborene Gibbusbildung mit Wirbelkörperspaltung an der Unteren Brustwirbelsäule. (Congenital Gibbus Formation with Cleft of the Body of Vertebra of the Lower Dorsal Region.) Walther Müller. *Arch. f. Orthop. u. Unfall-Chir.*, XXX, 319, 1931.

Five cases of this type of congenital deformity are cited, in which the diagnosis might have been confused with Pott's disease or fracture of the vertebra, were it not for the peculiar cleft of the body of the vertebra visible in the anteroposterior x-ray view, giving a butterfly-shape to the x-ray shadow. Müller emphasizes as an important characteristic of this deformity its location in the lower dorsal region, approximately in the middle of the primitive embryonic spinal segments. He believes that this location helps to explain the development of the deformity by a flexion of the primitive spine, coupled with some developmental anomaly of the vertebrae.—*Leo Mayer, M.D., New York, N. Y.*

INDIREKTER HALSWIRBELSÄULENBRUCH. (Indirect Fracture of a Cervical Vertebra.) Ludwig Strauss. *Arch. f. Orthop. u. Unfall-Chir.*, XXX, 331, 1931.

The author describes an unusual tear fracture of a small portion of the anterior border of the fifth cervical vertebra. The patient, a muscular man of thirty-two, following a vigorous swim, noted a sudden pain in the neck and right shoulder and inability to hold the head straight. The symptoms, however, were not severe enough to necessitate stopping work until five days later when, after swimming again, the pain became extreme, the patient noted marked weakness of the right arm and extreme pain at any attempt to move the head or arm. The lateral x-ray showed a tear fracture of the lower anterior margin of the body of the fifth lumbar. The fragment was about the size of a pea. The patient made an uneventful recovery after primary immobilization followed by physiotherapy.—*Leo Mayer, M.D., New York, N. Y.*

KLINIK UND PATHOLOGIE DES MALUM PERFORANS MIT BESONDERER BERÜCKSICHTIGUNG DER SKELETVERÄNDERUNGEN. (Clinical and Pathological Aspects of Malum Perforans with Particular Considerations of Skeletal Changes.) Oscar Scaglietti. *Arch. f. Orthop. u. Unfall-Chir.*, XXX, 392, 1931.

Three cases are described; in one amputation was performed, the other two patients died and were autopsied. One of the latter had tabes; the other two had no lesion of the central nervous system. The skeletal changes were followed in a series of roentgenograms and the final condition studied microscopically. Even before the ulcer had penetrated to the joint and thus infected it, the joint showed superficial necrosis of the cartilage and pannus formation. Following the infection of the metatarsophalangeal joint, extensive bony necrosis occurred, producing complete destruction of the joint and sequestration of the metatarsal bones and phalanges. This accounts for the characteristic shortening of the foot and the dorsiflexed position of the toes. A striking fact is that, after almost complete disappearance of a metatarsal bone, it can be almost completely regenerated. The microscopic changes incident to this regeneration could be traced in a large series of sections.

The paper though thorough, does not throw any additional light on the cause of malum perforans.—*Leo Mayer, M.D., New York, N. Y.*

VERSUCHE ÜBER RASCHE UND BLEIBENDE AUSFÜLLUNG VON OBERFLÄCHENDEFKTEN AN DEN FREIEN KNORPELKNOCHENENDEN DER GELENKE. (Experiments Dealing with Rapid, Permanent Filling of Superficial Defects of the Joint Cartilage.) Wilhelm Ammenwerth. *Arch. f. Orthop. u. Unfall-Chir.*, XXX, 435, 1931.

The knees of twenty dogs were operated on. A small bit of cartilage was removed with a gouge, exposing the bone. The defect was filled with a bit of muscle which was simply pressed into place. Although no fixation sutures of any kind were used and the animals were allowed immediate use of their limbs, in every case at autopsy the transplant was found *in situ*. In only a few of the earlier experiments was there any excess of joint fluid. In none were there arthritic changes. Microscopically the muscle showed a primary necrosis and gradual replacement with connective tissue. The cells on the surface assumed a parallel arrangement and gradually the spindle shape changed to a round form, resembling cartilage. Finally the tissue closely resembled fibrous cartilage.—*Leo Mayer, M.D., New York, N. Y.*

UNTERSUCHUNGEN ÜBER DIE HEREDITÄT ORTHOPÄDISCHER LEIDEN. III. DER ANGEBORENE SCHIEFHALS. (Researches Dealing with the Heredity of Orthopaedic Anomalies. III. Congenital Torticollis.) Eduard Isigkeit. *Arch. f. Orthop. u. Unfall-Chir.*, XXX, 459, 1931.

This article is a statistical survey of 2673 cases. The heredity factor could be proven in eleven per cent. The author rejects the traumatic theory of Strohmeyer

and the intra-uterine pressure theory of Petersen. He concludes that congenital torticollis is an hereditary anomaly, recessive in type,—probably of the dihybrid variety. It is influenced to a certain extent by external factors. Its pathology is and aplasia of the sternocleidomastoid, due to insufficient differentiation of the muscle tissue from the primitive mesenchyme. It is not the result of an abnormal intra-uterine position, but is rather the cause of such abnormal positions. In twins heredity could be demonstrated in twenty per cent. of the cases. The sexes were affected equally. Breach presentations and transverse positions occurred in fifty per cent.; difficult labor in seventy per cent. of the cases. The condition occurs more frequently in the first-born.—*Leo Mayer, M.D., New York, N. Y.*

Isolated Fracture of the Carpal Semilunar and Kienböck's Disease. T. B. Mouat, John Wilkie, and H. E. Harding. *British J. Surg.*, XIX, 577, April 1932.

Fracture of the carpal semilunar is not uncommon, though often unrecognized. The process of repair in the damaged bone is retarded by the defective blood supply and the poor reactive powers of its cartilaginous covering.

A slow progressive degeneration—"Kienböck's disease"—with absorption of necrotic bone lamellae and fibrous replacement, then takes place during a varying and often long quiescent interval, which is ultimately followed by deformation of the bone, with recurrence of the local symptoms and continued disability.

A similar local reaction may result from repeated minimal occupational traumata and in exceptional cases may be caused by an attenuated infection.

A Case of Parathyroid Tumour Associated with Fibrocystic Disease. G. Gordon-Taylor and Philip Wiles. With a Pathological Account by S. L. Baker. *British J. Surg.*, XIX, 606, April 1932.

A girl of twenty sustained a spontaneous fracture of the left femur due to localized cystic disease. Five months later the leg was amputated because of non-union. The parathyroid syndrome had not been recognized at this time. Two months later x-rays of all the long bones showed marked pathological changes. Three months later she sustained a fracture of the right femur. Exploration of the parathyroids revealed a definite tumor on one side and this was removed. Union then took place in the femur and the other bones became more normal.

A careful description is given of the parathyroid tumor and the bone tumors and also the results of careful blood chemistry at various stages of the disease.

Chronic Polyarthritis—Its Group Treatment. Rea Smith. *California and Western Med.*, XXXVI, 145, 1932.

The author starts with the premise that chronic polyarthritis is of intestinal origin either of bacterial toxins or metabolic products, and, after clearing up the other sources of infection, such as the teeth, tonsils, sinuses and pelvis, bases his main hope on elimination of toxins and bacteria from the bowel source. He proceeds to restore the normal flora of the bowel by an abdominal belt and sleeping with the pelvis raised and colonic irrigations and the implantation of acidophilus bacillus and diet. The purpose is to change the flora to a normal relationship between the gram.-negative and gram.-positive bacteria. Gastro-intestinal x-rays are taken and special notice is made of the motility of the caecum. In case of an immobile caecum, then operative mobilization must be done, else the intestinal flora will return to its old imbalance.

The operative work is based on the conception that the descent and fusion of the ceacum causes pinching of Auerbach's plexus, and that the caecum dialates and becomes thin, pale, and apparently atrophic. The technique is described in detail. The author finds no other method to be of value for this purpose by reason of the primary cause being the pinching of the nervous plexus; and plicating the caecum would defeat its

object because it would give no relief to the plexus. Any kind of mechanical fixation of any part of the caecum prevents the contraction of the longitudinal bands. The author has never had to re-operate for recurrence of the membrane in a series of about three hundred cases extending over a period of twelve years.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

SEMILUNAR CARTILAGES—THEIR REMOVAL FROM THE KNEE JOINT. George J. McChesney. *California and Western Med.*, XXXVII, 98, 1932.

The author reports on twenty-seven cases referred to him by various insurance companies. The average age was forty-one years; the average time from injury to operation was five months, and from operation to examination by the author seven months. There was crepitation in all cases, and locking in thirty-seven per cent.; tenderness was frequent. Complete extension could be obtained, though the quadriceps was usually atrophied. The x-ray showed arthritis in fifty per cent.

He also investigated the records of the California Industrial Commission for 1930 and found over half of the cases to have been rated more than ten per cent. disability. He quotes D'Arcy Power's report in the *British Medical Journal* (I, 61, 1911) on eighty-nine cases in which seventy-three had no return of symptoms; sixteen experienced recurrences; fifty reported normal strength, while thirty-nine complained of weakness.

He believes that the reasons for such a high disability rating in this country were lack of cooperation by the patient or his desire to obtain a higher rating, the climatic conditions, the nature of the work to which the patient returned or—what was more important—the age of forty-one. He also believes that many cases are improperly diagnosed and that operation is often unnecessary.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

THE TREATMENT OF FRACTURES, BY MEANS OF SKELETAL DEVICES. H. W. ORR, *J. Am. Med. Assn.*, XCVIII, 947, 1932.

Because the modern demand in the treatment of fractures is for correct anatomical replacement of injured parts and recovery with a maximum of function, and because of the low percentage of first class results from the use of weight and pulley or elastic traction, and the inefficient methods of fixed traction in splints, technique must be improved in the primary reduction and the control of the fracture and patient during the period of healing. The use of skeletal traction devices and the incorporation of these fixation devices in a plaster-of-Paris cast has given better control of the fracture than any other splint.—*Ruth Jackson, M.D., Dallas, Texas.*

ARTHRITIS OF THE CERVICAL SPINE. Some Neurologic Manifestations. J. Dewey Bisgard. *J. Am. Med. Assn.*, XCVIII, 1961, 1932.

Recent investigations have shown that radiculitis of arthritic origin is a common manifestation of vertebral arthritis, and in magnitude these radicular symptoms far exceed symptoms referable to the local arthritic process, thus producing many variable and bizarre symptom complexes which receive many different diagnoses. Not only is this radiculitis manifest in the symptoms, but also it is frequently betrayed by sensory and motor changes in the involved areas.

Symptoms of sixty cases of arthritis of the cervical spine are analyzed and ten illustrative case histories emphasize the remoteness of local symptoms of arthritis as compared to the symptoms, sensory and motor findings which predominate and which are due to radiculitis from the arthritic process.

History of cases in which there was complaint of occipital and suboccipital headaches could be explained by radiculitis of the cervical spine. Thirty-eight had pain, tenderness, stiffness, and crepitation, localized in the neck; eight had "neuritis" in the shoulders and arms; five noted marked sensory disturbances in hands and arms, and four showed definite motor nerve involvement, all as a result of involvement of

the nerve radicles by the lipping and osteophytic outgrowths of chronic vertebral arthritis.—*W. B. Carrell, M.D., Dallas, Texas.*

NON-TUBERCULOUS ARTHRITIS. A Descriptive Classification. M. J. Shapiro. *J. Am. Med. Assn.*, XCVIII, 1965, 1932.

The author refers to the original work of Nichols and Richardson who found only two groups into which arthritis would invariably fall,—namely, the proliferative and the degenerative types. These groups do not necessarily differ in etiology since one group sometimes merges into the other and of two persons having identical clinical manifestations one may show the degenerative and the other the proliferative type of pathology.

A recent review of the literature by the author finds that the workers in this field are using several different classifications of arthritis, and he shows how many of these classifications are not scientifically sound, as some are based on etiology and some on roentgenographic appearance. Since the etiology of many arthritides is still unknown, roentgenographic views of the same process may vary from time to time.

The classification proposed by the American Committee is too stiff and unflexible, and cannot be followed in classifying every case of arthritis; hence, the author presents a new classification which, although it is somewhat cumbersome, is nevertheless entirely adequate to classify any case of arthritis, since it is based on descriptive terms pertaining to arthritis, the meanings of which are unmistakable. This classification takes into consideration in the naming of a particular case of arthritis, its clinical aspect, etiological, pathological, anatomical, and roentgenographic aspects and whether it is monarticular or polyarticular.—*W. B. Carrell, M.D., Dallas, Texas.*

THE ORTHOPEDIC TREATMENT OF INFANTILE PARALYSIS. Charles Leroy Lowman. *Northwest Med.*, XXXI, 136, 1932.

The author states that the orthopaedic treatment of infantile paralysis should begin simultaneously with the medical treatment, and that deformity need not exist in more than one per cent. of the cases. Mixed polyvalent convalescent serum is now used and evidently is an aid as a therapeutic agent. In case serum cannot be obtained, whole blood from a recovered case may be transfused into the abdominal muscles. Physiological rest should be maintained; too early massage and manipulation will often produce more crippling. The pain in the muscles may tempt the mother to raise the knees on a pillow, thus contributing towards deformity. She may at times allow the bed clothes to stretch the paralyzed tibialis anticus and produce more foot drop. Good bed posture contributes towards less paralysis and no deforming contractures. The acute muscle soreness and neuritis are relieved by casts and plasters half-splints. Deformity is a secondary condition, especially if postural faults exist prior to the disease. Parents must be taught the nature of the disease and the why and wherefore of the treatment, as it may save unnecessary disability and loss of time through neglected cases. The physiological splinting treatment should continue for six or seven weeks, then reeducational exercises should be started without pain or fatigue, the weight being carried by an assistant.

The warm pool is a valuable addition to muscle reeducation, and is begun just after quarantine or at the end of the fourth week; if there is no kidney contra-indication. The physiological demand for nutrition of muscles is in direct ratio to the activation and hence they are nourished and no atrophy occurs. The purpose of muscle training is the reopening of the neural channels from the brain and this is more rapidly arrived at by the more free underwater exercises, where the reflex arcs and neural patterns are formed by reason of the sense of motion. The dosage must not reach fatigue.

Operative reconstruction is considered. In old cases the deformity is first corrected, then reeducation is begun.

The child's social and educational outlook should be given consideration to enable him to meet the new conditions.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

CHRONIC ATROPHIC ARTHRITIS: ITS MODERN CONCEPTIONS. Edward A. Rich. *Northwest Med.*, XXXI, 327, July, 1932.

The author believes that atrophic arthritis is a constitutional disorder resulting in vascular deficiencies, and not caused by local infection. He considers it a vasomotor constriction disease which produces a vicious cycle when the arthritic structures become atonic. The patients belong to a class complaining of inanition and chronic fatigue and are often diagnosed as "run down", "overworked", or "anaemic". The patients are scant eaters and dislike fats. The prodromal stage is characterized by asthenia and avascularity. The fingers become numb and spindle-shaped. There is a history of sudden joint involvement following some debilitating disease. The terminal stage presents soreness and stiffness of the joints followed by absorption and ankylosis.

It is only cured in the preliminary stage when the underlying vascular deficiencies can be successfully treated. The medical profession should be ever alert to on-coming arthritis in asthenic cases. The author believes that the recovery of streptococcus from the periarticular structures means no more than their recovery from any other anatomical area.—*Charles Lyle Hawk, M.D., Los Angeles, California.*

ANOMALIES OF THE LOWER SPINE: CONSEQUENCES AND TREATMENT. R. R. Vreden. *Orthopaedia i Travmatologia*, V, No. 4, p. 5, 1931.

A modified Putti classification of the anomalies of the lumbosacral spine is proposed. They are divided into four groups:

Anomalies of differentiation of the vertebrae,
Anomalies concerning the number of the vertebrae,
Anomalies affecting the form of the body and parts of the vertebrae,
Various and simultaneous combination of the previous anomalies.

A detailed analysis of the symptoms observed in each group is given. The method of treatment is dictated by several factors: age, social status, etiology, and degree of deformity. At an early age conservative treatment is indicated. Between eight and fifteen years an osteoplastic fusion in the corrected position is advised. The only radical procedure is a stable immobilization of the lower lumbar vertebrae and the sacrum by means of fusion. In rare cases of spina bifida sacralis, a resection of the spinous process of the fifth lumbar is added. A series of 104 patients have been operated upon. Henle's, Whitman's, Halstead's, and the author's methods of operation were used. The results were gratifying, although in several cases consecutive physiotherapy was necessary. In five per cent. of the operated cases, intestinal manifestations, simulating obstruction, were observed which were probably due to thrombosis of the mesenteric veins widely anastomosing with the pelvic veins. There was no mortality in this series.—*Emanuel Kaplan, M.D., New York, N. Y.*

HABITUAL DISLOCATION OF THE HUMERUS. B. K. Babitch. *Orthopaedia i Travmatologia*, V, No. 4, p. 29, 1931.

The author reviews the anatomy, etiology, pathology, and mechanism of this affliction. Twenty-five patients were under observation. The operative treatment is considered the best, although there are numerous procedures,—Oudard found 150 different methods of operation.

Eleven patients were operated upon at the Ukrainian Institute of Orthopaedic Surgery and Traumatology; postoperative duration three and one-half years to six months, results very satisfactory. Seidel's technique modified by Sitenco was used. A longitudinal incision, ten to twelve centimeters long, is made over the anterolateral aspect of the shoulder, exposing the capsule through the deltoid, followed by external rotation of the arm and division of the tendon of the subscapularis at the lesser tuberosity of

the humerus. A strip of fascia lata, seventeen centimeters by three centimeters, is then inserted at the medio-inferior angle of the joint capsule and, after internal rotation of the arm, is drawn across in front of the joint upward and externally. The fascial strip is then passed under the deltoid and attached to the acromion. An abduction splint is applied and motion and massage started on the tenth day; the splint is removed on the fifteenth day.—*Emanuel Kaplan, M.D., New York, N. Y.*

Undescended Scapula with an Omovertebral Bone. Byron H. Jackson. *Radiology*, XIX, 67, 1932.

This article is a study of a case of undescended scapula, with an omovertebral bone connecting the upper half of the vertebral border of the left scapula to the cervical spine.

The patient suffers no restriction of activity from his deformity except inability to elevate the arm above the horizontal plane, being able to engage in athletic sports and to function as a coal miner. He is well developed and healthy. His whole left chest and shoulder girdle are higher than his right. The left shoulder and clavicle are thrown forward about one inch in front of his right and the lower half of his neck is much wider than the right. The lower angle of the left scapula is three and one-half inches higher than the right. The superior border bends sharply forward. There is a dorsal scoliosis, with convexity to the right. Occupying the usual position of the normal superior vertebral angle is an oblique border three and three-quarters inches long, to which is attached, by cartilage, a triangular bridge of bone five inches long, its apex extending upward to a firm attachment to the third or fourth cervical spine.

The terms "Sprengel's Deformity" and "Congenital Elevation of the Scapula" are objectionable for this condition, which is actually due to failure of descent of the scapula and should be known as "Undescended Scapula".

"The arm of the human embryo is cervical in position. It descends during the second month."

Undescended scapula is always accompanied by other defects or anomalies,—*viz:*

Defects of the cervical spine with or without an omovertebral bone.

Defects of muscles with or without bony defects.

An omovertebral bone, without defects of the cervical spine.

These represent the three forms of the condition.

The forward bending of the supraspinous portion of the scapula is common to all types of undescended scapula, due to the molding of muscles on the bone retained in its original embryonic position.

The common characteristics of omovertebral bones, as reported in the literature, are:

They are attached to the scapula by cartilage, just as rib is attached to the sternum.

They have articular facets by which they are attached to the cervical spine.

They are provided with tubercles.

In composition they resemble ribs.

The author believes that omovertebral bones represent cervical ribs, arising from vertebrae above the seventh cervical and attaching by their costal cartilage to the scapula, with which they come in contact during the first few months of intra-uterine life.—*Edward N. Reed, M.D., Santa Monica, California.*

Sur un Nouveau Procédé d'Arthrodèse-Résection de la Hanche et d'Ostéotomie dans les Coxalgies Anciennes et Arthrites Déformantes. Jacques Calvé. (Société Belge d'Orthopédie, November 1931.) *Scalpel*, LXXXV, 373, 1932.

Dr. Calvé describes a new technique for arthrodesis of the hip, worked out on the cadaver, and presented before the Belgian Orthopaedic Society. In brief, the method consists of opening the area of the hip joint through a lateral vertical incision, opening the capsule above, section of the trochanter by an inverted Y osteotomy, separating

the two fragments laterally, but preserving the aponeurotic attachments, section of the neck, removal of neck and head, with thorough cleaning of the diseased area. The limb is then put into the desired position and the two trochanter fragments put into place, making a live graft on either side between the diaphysis and the ilium.

FRACTURES OF THE SHAFT OF THE FEMUR. S. O. Black. *Southern Med. J.*, XXV, 739, July, 1932.

For children under sixteen years of age, skin traction is used; for adults, skeletal traction combined with Thomas splint and suspension. Ice tongs with the knee flexion on a Pearson flexion attachment is the method of choice. Traction for six to eight weeks, then protection in bed two or three weeks longer is necessary. Then a caliper splint should be applied and walking started. Plaster-of-Paris has been practically abandoned in the treatment of fractures of the femur. When traction fails, the Sherman technique of open operation and internal fixation with metal plates is used. Should non-union occur, a massive onlay autogenous bone graft is advised.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

FRACTURES OF THE PELVIS. G. W. Leadbetter. *Southern Med. J.*, XXV, 742, July, 1932.

The treatment of fracture of the pelvis by allowing the patient to rest in bed, and applying an adhesive strap or two, or an encircling belt is, in the large percentage of cases, no treatment at all. Accurate diagnosis by means of stereoroentgenographs is the first essential. Then the presence of any serious complications should be determined. An effort should be made to restore and preserve the continuity of the pelvic ring. Cases with definite dislocation of fragments are treated by suspension and traction. A Balkan frame, Thomas splints, and adhesive traction are first used. If these do not succeed in proper reduction, skeletal traction is used. Traction is kept up about six weeks; then rest in bed with a pelvic belt about two weeks. Walking is started about the tenth week. Open operation has been done in very few cases.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

PRIMARY OSTEOMYELITIS (CHRONIC FIBROUS) OF THE ANTERIOR SUPERIOR SPINE OF THE ILIUM. Report of a Case. R. C. Robertson. *Southern Med. J.*, XXV, 825, Aug. 1932.

A boy thirteeen years of age had pain and swelling, in region of the anterior superior spine. Slight rise in temperature. X-ray showed a small area of destruction in this region. Diagnosed as primary malignancy; four treatments of deep x-ray therapy were given. Pain and limp disappeared. Was free of symptoms for three months. Symptoms returned. Exploratory operation under ether: schlerotic areas with grayish soft tissue cleaned out. Cultures showed staphylococcus aureus. Microscopically fibrous tissue only was found. After two years patient is entirely well.—*Fred G. Hodgson, M.D., Atlanta, Georgia.*

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